

Should we screen for colorectal cancer in people aged 75 and over? A systematic review - collaborative work of the French geriatric oncology society (SOFOG) and the French federation of digestive oncology (FFCD)

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RESEARCH

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Should we screen for colorectal cancer in people aged 75 and over? A systematic review - collaborative work of the French geriatric oncology society (SOFOG) and the French federation of digestive oncology (FFCD)

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Abstract

Background We have done a systematic literature review about CRC Screening over 75 years old in order to update knowledge and make recommendations.

Methods PUBMED database was searched in October 2021 for articles published on CRC screening in the elderly, and generated 249 articles. Further searches were made to find articles on the acceptability, efficacy, and harms of screening in this population, together with the state of international guidelines.

Results Most benefit-risk data on CRC screening in the over 75 s derived from simulation studies. Most guidelines recommend stopping cancer screening at the age of 75. In private health systems, extension of screening up to 80–85 years is, based on the life expectancy and the history of screening. Screening remains effective in populations without comorbidity given their better life-expectancy. Serious adverse events of colonoscopy increase with age and can outweigh the benefit of screening. The great majority of reviews concluded that screening between 75 and 85 years must be decided case by case.

Conclusion The current literature does not allow Evidence-Based Medicine propositions for mass screening above 75 years old. As some subjects over 75 years may benefit from CRC screening, we discussed ways to introduce CRC screening in France in the 75–80 age group.

IRB An institutional review board composed of members of the 2 learned societies (SOFOG and FFCD) defined the issues of interest, followed the evolution of the work and reviewed and validated the report.

Keywords Harms, Simulation, Cost effectiveness, Acceptability

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Introduction

In Europe, colorectal cancer (CRC) incidence and mortality rates have been stable or have slightly decreased over the past ten years [1, 2]. In France, the same trends are observed with estimated standardized incidence rates for 2018 of 55.3/100,000 for men and 36.7/100,000 for women [1, 3]. The median age at diagnosis was 71 for males and 73 for females, and almost half of CRC occurred after 75 years in women, 40% in men. CRC incidence increase with age: in France from 49.8/100,000 for men [50–54 years] to 414.1 [80-84], and respectively 43.1 to 256.4 for women [4]. Data about adenoma incidence are scarce, a 24-year study in France showed that adenoma incidence increases with age too, and reaches a maximum at 75 years for women and 80 years for men [5]. Given the high incidence rate, the long preclinical phase, the treatable precursor, and a curative treatment for early-stage disease, CRC fulfils the WHO criteria for screening [6] (1: Important health problem, 2: accepted treatment for recognized disease, 3: facilities for diagnosis and treatment, 4: suitable latent and symptomatic stage, 5: suitable test or examination, 6: test acceptable to population, 7: natural history of condition understood, 8: agreed on policy on whom to treat, 9: Cost of finding economically balanced with overall health, 10: case finding should be continuous process).

A comparison with six European countries showed there was no significant difference in CRC net survival. Five-year CRC net survival increased between 1992 and 2004 and reached 64% for colon cancer and 62% for rectal cancer, and the gain was related to a decrease in the excess mortality during the first 18 months after diagnosis for colon cancer and the first 24 months for rectal cancer. This reflects the progress made in the initial management of CRC and underlines the need to implement and improve mass CRC screening [7, 8], which makes it possible to diagnose CRCs at very early stages and to treat them curatively more often with fewer complications.

CRC mass-screening programs have been implemented in several countries worldwide. In 2003, the Council of the European Union recommended that all Member States should establish CRC screening programs for individuals aged 50 to 74 years, with an annual or biennial fecal occult blood test (FOBT), followed by colonoscopy when the results were positive [9]. In 2015, 24 European countries had established CRC screening programs. In the US, opportunistic-based screening programs have been established: participants choose among several options: annual FOBT, multi-target stool DNA test every 3 years, flexible sigmoidoscopy every 5 years, colonoscopy every 10 years, double contrast barium enema or CT colonography every 5 years [10]. In Canada, Chile, Asia and Australia, annual or biennial FIT-based programs have been implemented [11].

In France, an organised national CRC screening programme has been implemented since 2009, for individuals aged 50 to 74 at average risk, using a single-sample FOBT every two years (guaiac FOBT until 2015, FIT since 2015), followed by a colonoscopy if the result is positive. The chosen cut-off value is 30 µg Hb/g feces with the OC-Sensor®.

The CRC mass screening participation rate in France is low, 34.6% for the 2020–2021 round, far from the 45% rate recommended by the European Council as the minimum target rate. This rate is better for females (35.7%) than for males (33.5%) and increases with age from 31.9% [50–54 years] to 39.6% [70–74 years] for males and 33.5% to 39.5% for females. (https://www.santepubliquefrance.fr). The proportion of subjects fulfilling exclusion criteria for CRC screening increased with age, from 5.4% [50–54 years] to 25.1% [70–74 years] for males and from 6.3% to 21.3% for females.

The positive predictive value of a positive test for CRC increased with age, from 4.0% [50–54 years] to 10.2% [70–74 years], and from 27.6% [50–54 years] to 31.9% [70–74 years] for advanced adenoma ($\geq$1 cm, high-risk dysplasia, or villous component).

The French population is ageing and life expectancy at 75 years is increasing, reaching 12 years for men and 14.8 years for women, and respectively 8.9 years and 10.1 years at 80 years (https://www.insee.fr/fr/statistiques accessed in September 2020). The increased incidence of CRC and advanced adenoma with age suggests that screening people over 75 years would be beneficial, while the decrease in residual life expectancy suggests the opposite.

Harm associated with screening includes fear and anxiety, inconvenience, and complications due to the diagnostic procedures. A more complex risk of screening is overdiagnosis and overtreatment (Fig. 1). Overdiagnosis is defined as a diagnosis of a disease which would not have been detected in the absence of screening during the whole life of the subjects, and would have no consequence on his life expectancy [12, 13]. Overdiagnosis may induce overtreatment, as defined by treatments applied to patients in the context of overdiagnosis, which have no impact on their health/life. Overdiagnosis and overtreatment are statistical concepts, and it is not possible to state, for a specific subject, whether the detected lesion would have been detected in the absence of screening or not. Considering the life expectancy of elderly, the risk of overdiagnosis is certainly greater.

The aim of our work was to update knowledge about CRC screening in older individuals by conducting a review of the literature and to make recommendations.

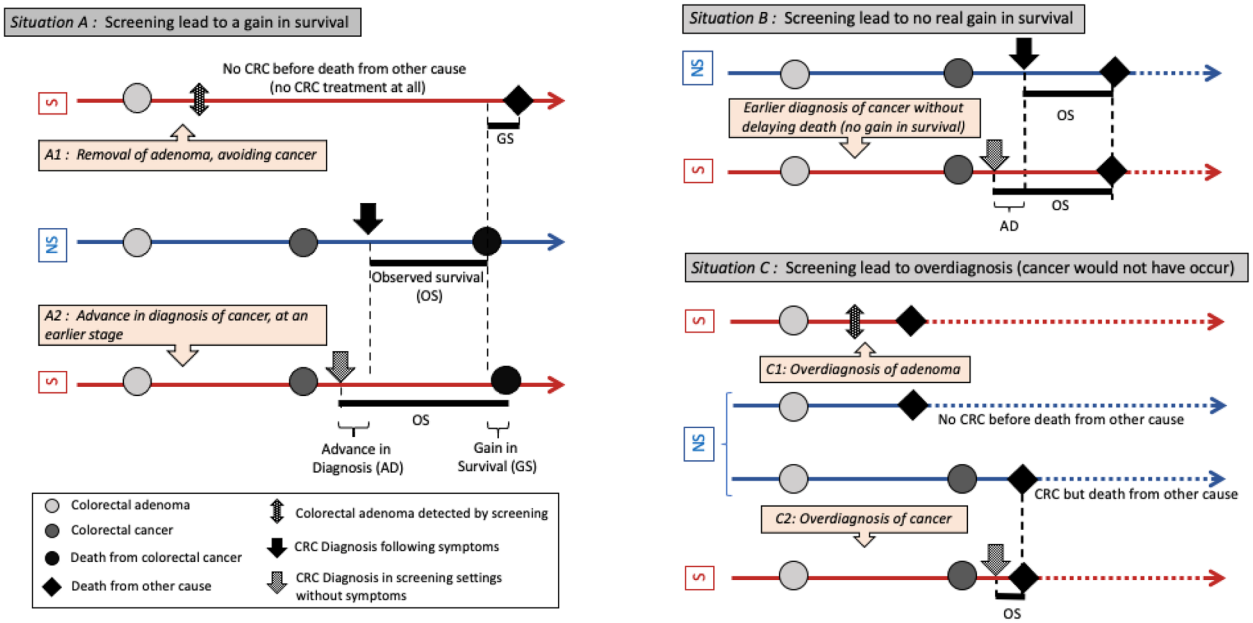


Fig. 1 Screening and natural history of colorectal adenoma and cancer

Methods

The benefit-risk ratio of CRC screening in the elderly was based on a search of the literature concerning key principles in cancer screening: detection of cancer in asymptomatic individuals, analysis of the benefit-risk ratio. CRC screening strategies include one-step screening by colonoscopy, or two-step screening with a first triage test followed, when positive, by a colonoscopy.

The literature search was conducted using the PUBMED database, to identify review articles published on colorectal cancer screening in the elderly. The methodological filters used were English, Review and Meta-analysis. The relevant articles were extracted in October 2021. The search equation combined Medical (MeSH) terms as follows: ("Aged"[Mesh] OR "Aged, 80 and over"[Mesh] OR "Geriatrics"[Mesh] OR elderly) AND (“Mass screening”[Mesh] OR screen*) AND ("Colorectal Neoplasms/diagnosis"[Mesh] OR “colorectal cancer”).

The titles and abstracts of the 249 articles retrieved were analyzed by three physicians (VQ, LG, SM), to select relevant articles for a population older than 75 years old. Cross-references and related articles were used to enrich the literature search, and complementary searches were performed to find other articles on the acceptability, efficacy, cost-effectiveness, and harms of screening in this population, together with the state of international guidelines. The questions addressed by the working group were: What observed data are available? What are the side effects of screening in this population? How effective is screening in this population? What is the cost-effectiveness of screening in this population? What acceptability? What are the results of existing reviews? What are the international recommendations?

Results

Observed data on CRC screening in the elderly

There is no randomized controlled trial on the efficacy of extending CRC screening over 75 years. Of the four RCTs on efficacy of FOBT screening, only the Minnesota trial [14] evaluated screening until 80 years, and no data are available on the specific results in the 75–80 years age subgroup. The few data available on CRC screening in elderly subjects [15–17] demonstrated larger detection rates of significant adenomas and CRC in elderly than in the younger population (about 5% to 10% increase) (Table 1).

Adverse events associated with endoscopic procedures in the elderly population

Serious adverse events comprise perforation, bleeding, cardio-vascular event, pulmonary event, general anaesthesia-related event, and death (Table 2). These adverse events can outweigh the benefits of screening. Adverse events rates reported in the elderly frequently came from studies in which the colonoscopy was done for reasons other than screening alone. The great majority of guidelines, reviews and studies report an increased risk of serious endoscopic-related complications after 75 years [18–36]. The risks of perforation and bleeding doubled after 75 years (10.3/10,000) compared to 70–74 years

Table 1 Observed data on colorectal cancer (CRC) screening in the elderly

Study	Type of study	Population	FOBT positivity rate / colonoscopy rate	Lesion detection rate
Lin, 2006 [16]	Cross-sectional monocenter study	1,244 average-risk asymptomatic colonoscopy-screened subjects (147 aged 75–79, and 63 over 80y,) in one US center	NA	Advanced neoplasia (including CRC) rate: 3.2% in 50-54y, 4.7% in 75–79 and 14.3% in 80 + 2 invasive cancers in 50–54 and 1 in 80 +
Kirstler, 2011 [17]	Longitudinal cohort study (7 years of follow-up)	212 average-risk subjects (75 aged 70-74y, 93 aged 75-79y, and 44 aged over 80y) with positive FOBT in four US centers	Colonoscopy rate after positive FOBT: 56%	Significantadenomas rate: 29% in 70 + (of which 79% still alive at 5 yrs) 6 cancers 46% of patients without colonoscopy died from other cause than CRC within 5yrs after the test
Koivogui, 2019 [15]	No follow-up data	18,704 average-risk subjects corresponding to 18,995 FOBT tests in 11 French districts (15,855 aged 75y, 2,545 aged 76-80y, and 595 aged 80y)	FOBT positivity rate: 3.7% in this 75 +, vs 2.9 overall Colonoscopy rate: 81.3% in 75 +, vs 81.9% overall	Neoplasia rate: 19.3% in 75 +, vs 14.1% overall Cancer rate: 3.7% in 75 +, vs 1.8% overall Predictive positive value (PPV) for CRC: 12.2% in 75 +, vs 7.4% overall PPV for neoplasia: 63.7% in 75 +, vs 58.8% overall

CRC colorectal cancer, *FOBT* fecal occult blood test, *PPV* predictive positive value

Table 2 Risk of colonoscopy-related complications for 1 000 individuals

Study	Type of study	Population	Perforation (‰)	Gastrointestinal bleeding (‰)	Cardiovascular (CV), respiratory (R) (‰)	Death (‰)
Day LW, 2011 [25]	Review All indications		≥ 65y: 0 to 6.6 ≥ 80y: 0 to10.5	≥ 65y: 0 to 14.9 ≥ 80y: 0 to 9.1	≥ 65y: 25.9 ≥ 80y: 34.8	≥ 65y: 0 to 1 ≥ 80y: 0 to 9.7
Ure T, 1995 [35]	Case–control All indications	354 ≥ 70y 302 < 70y	0 0	0.2 0.2		0 0
Warren JL, 2009 [31]	Population-based All indications 66–95 years	53,220 Screening population ($n = 5,349$)	0.1 2.8 66-69y: 5.0 70-74y: 5.8 75-79y: 7.2 80-84y: 8.8 ≥ 85y: 12.1	1.8	CV: 16.6 CV: 12.5 66-69y: 12.6 70-74y: 16.0 75-79y: 20.6 80-84y: 25.7 ≥ 85y: 31.8	
Rutter CM, 2012 [23]	Cohort Screening and follow-up colonoscopy 40–85 years	43,456 (158,295 colonoscopies)	0.5 40-49y: 0 50-64y: 0.3 65-74y: 1.0 75-85y: 1.7	2.8 40-49y: 2.3 50-64y: 2.1 65-74y: 4.3 75-85y: 8.1		0.3 40-49y: 0 50-64y: 0.3 65-74y: 0.4 75-85y: 1.3
Ko CW, 2010 [24]	Cohort Screening and Follow-up colonoscopy > 40 years	21,375	0.19 40-59y: 1.2 60-69y: 1.8 70-79y: 3.5 ≥ 80y: 4.4	0.6	CV: 4.9 R: 7.5	
Garcia-Albeniz X, 2017 [32, 33]	Population-based screening population 70–79 years	1,355,692	70–74: 0.4 75–79: 0.4	70–74: 0.4 75–79: 0.5	70–74: 10.7 75–79: 18.1	
Causada-Calo N, 2020 [34]	Population-based cohort Individuals with average colorectal cancer risk	30 443: 50-74y 7 626 ≥ 75	0.4 0.8 NS	3.0 9.0 $p < 0.001$	CV: 5.0 CV: 18.0 $p < 0.001$	

(5.6/10,000) [273334]. Adverse events from colonoscopy increase by 10% after age 65, and the risk of perforation by 30% [2631]. Cardiovascular and pulmonary complications related to anaesthesia increased from 26/1000 after 65 years to 35/1000 after 80 years [2631].

For two authors, age alone must not be considered as a factor that increases the risk of colonoscopy adverse events [23, 37, 38]. For others, age is an independent factor associated with an increase in colonoscopy-related perforation and bleeding [23, 39]. For the authors of the American Cancer Society guidelines 2018, age and comorbidity increase the risk of colonoscopy adverse events and must be considered together and not separately [33]. In addition Day LW et al. mentioned that colon cleansing is more difficult to achieve in the elderly, considered insufficient in 4% to 57% of studies, and that a complete colonoscopy is less frequently achieved, in only 78% to 86% of cases [26, 29].

The use of computed tomographic colonography (CTC) is proposed to reduce the risk of optical colonoscopy (OC), especially the risk of gastrointestinal bleeding, perforation and cardiovascular events [40, 41]. A meta-analysis found a 0.5% risk of severe adverse effects in individuals over 65 years, 0.2% in asymptomatic individuals [42]. Two large non-randomized studies found no significant difference in perforation rates between CTC and OC. This may be due to better detection of microperforation with no clinical consequences [40, 41]. CTC requires neither intravenous analgesia nor sedation, but spasmolytic agents may be used to improve image quality [41]. Spasmolytic agents have anticholinergic effects, with potential cardiac and ocular side-effects, as well as antimuscarinic effects on the urinary bladder. Bowel preparation is similar to that for optical colonoscopy, and in case of neoplasia detection, an optical colonoscopy is required to further explore the lesion, or to perform polypectomy. Furthermore, CTC can lead to the detection of extracolonic lesions.

Effectiveness of screening in this population

The only available data on the benefit-risk of CRC screening in this population arise from simulation studies [17, 18, 24, 43–47] (Table 3). In these studies, the sensitivity and specificity of tests were assumed not to vary with

age, although a decrease in specificity might be observed in the elderly for FITs, for example, due to other causes of bleeding [23]. All of these studies excepted one [44], supposed adherence to the screening strategy from the age 50 until the stipulated age for the end of screening. Data used in simulations were US data only for both CRC incidence/mortality, and life expectancy.

The benefits of screening decreased with age and comorbidity. The potential for screening-related complications was greater than the estimated benefit in some population subgroups aged 70 years and older. Nonetheless, at all ages and life expectancies, the potential reduction in mortality from screening outweighed the risk of colonoscopy-related death. Colonoscopy screening provided the greatest benefit but also the highest risk of complications.

One of these simulation studies determined up to what age CRC screening should be considered in unscreened elderly people according to comorbidities and the choice of test [44]. The effectiveness and the cost-effectiveness of the screening program decreased with age, and colonoscopy was the most effective and most expensive. The decline in effectiveness is explained by the increased risk of death from other causes with age, the harms of colonoscopy, overdiagnosis and overtreatment. Screening remains effective in populations without comorbidity. Van Hees et al. also showed that comorbidity was an important determinant of the harms and benefits of screening in the decision to stop screening [44].

A recent U.S. simulation model that included screening history and life expectancy revealed a wide age range for stopping screening, between 66 and 90 years of age. The subjects ranged from unhealthy people with perfect screening histories to healthy people with no prior screening [47].

Finally, one simulation study evaluated the age at which screening provided similar harms and benefits to those found with screening at age 74 in average-health individuals. The findings indicated that screening should be stopped before 75 in some populations, and even before 70 years in subjects with severe comorbidities [52].

Cost-effectiveness

Taking a willingness-to-pay threshold of $100.000/QALY, it has been shown that screening with colonoscopy remains cost-effective with increasing age, even in the oldest age groups [53]. In such cost-effectiveness analyses, the impact of the reduced life expectancy in the elderly is compensated by the higher diagnostic yield of screening endoscopy. However, screening colonoscopy in elderly persons (aged > 80 years) results in only 15% of the expected gain in life expectancy reached in younger patients [17].

Two reviews concluded that screening in subjects over 70 years [23] or 75 years [54] was not or less cost-effective than in younger people, with a low level of evidence. The 2019 simulation-model cost-effectiveness study done in France concluded that extending the upper-age limit to 80 years in a FIT/2 years-based screening program, with a 30% participation rate would result in a 5% decrease in CRC mortality, a 1% decrease in CRC incidence, and a 16% increase in cost [55].

Acceptability of screening

A cohort study [56] of 27,404 individuals aged 65 years or more, screened for breast, prostate, cervical or colorectal cancers showed that CRC screening was continued in 50.8% to 40.8% according to their 9-year mortality risk, and in 48.5% to 40.8% according to their 5-year mortality risk. The only factor associated with the discontinuation of screening was age greater than 80 years for both 9- and 5-year mortality risk. Similar findings were observed in another study on 27,068 Veterans older than 70 years of age in the USA [57].

In a French study, 4,268 individuals aged 70–74 years with no prior screening were invited in 1988 to do a Hemoccult® test every 2 years until 2002 (they were aged 84–88 years at this time), and were followed up until 2009. The participation rates were good (≥ 40%) up to age 78 and satisfactory (≥ 30%) up to age 80. A modest (10%) not significant reduction in mortality was observed (standardized mortality ratio 0.90 [95%CI 0.73–1.11]). No data about comorbidities were available [58].

The acceptability of repeated colorectal cancer screening with a FOBT, in a population aged 60 to 70 years could be based on perceptions of remaining life expectancy. Those expecting to reach ≥ 90 were more likely to accept repeated screening than those expecting to die before 80 years [59]. In elderly patients, information affected perception of the efficacy of screening tests but not their preference [60].

Data on colonoscopy rate after a positive FOBT are scare, and divergent (see Table 1) [16, 18].

Synthesis of data from narrative reviews

Some reviews [22, 61, 62] concluded that there were no sufficient data in the literature to recommend screening after 74 years. Other reviews concluded that there was probably a screening benefit for the elderly especially if they had no history of screening and if their life expectancy was at least 10 years [23, 27, 29, 63, 64], or at least 7 year [19]. The benefits of screening decrease with age, significantly after 80 years, and become null at 85 years for men and 90 years for women [27, 29]. Pasetto et al. [65] reasoned that screening is efficient until 80 years for individuals not up to date with screening, with a 5-year

Table 3 Simulation results on colorectal cancer (CRC) efficacy, effectiveness and cost-effectiveness in the elderly

Study	Screening test	Simulation methods, and underlying assumptions	Efficacy based on simulation results
Ko, 2005 [23]	FOBT, flexible sigmoidoscopy, colonoscopy	US life expectancy tables, SEER program CRC mortality rates Decrease in CRC mortality at 5 years (assumption): - FOBT 18% - Flexible sigmoidoscopy 40% - Colonoscopy 75% No decrease in mortality in the first 5 years after the screening test	Number needed to screen increased with age and with the reduction of life expectancy Colonoscopy-related complications increased with age Complications outweighed benefits for - Women 75-79y, men 70-74y in poor health status - Women 85-89y, men 90-94y in average health status No benefit from screening if life expectancy < 5 years
Lin, 2006 [16]	Colonoscopy	US life expectancy tables / SEER program CRC mortality rates Life expectancy estimated with and without screening according to sex, age and colonoscopy findings, considering polyp lag time and transforming rate, No complication of colonoscopy was simulated	Simulated life expectancy extension: - 0.85 years (2.9%) in 50-54y - 0.17 (1.6%) in 75-79y - 0.13 (1.7%) in ≥ 80y Patient benefit: - 6.0% in 50-54y - 12.2% in 75-79y - 15.9% in ≥ 80y Number of colonoscopies per life year saved - 1.18 in 50-54y - 5.77 in 75-79y - 7.95 in ≥ 80y
Zauber, 2008 [42]	FOBT, flexible sigmoidoscopy or colonoscopy	US life expectancy tables / SEER program CRC mortality rates, MISCAN and SimCRC models, Sensitivity and specificity supposed constant according to age	Increase in number of colonoscopies (D-COL) and in LYG (D-LYG) by extending CRC screening from 50–75 to 50-85y age / 1.000 subjects Biennial FIT: - D-COL = 212 D-LYG = 8 (+ 4.0%) - Efficiency ratio D-COL/D-LYG = 26,5 Decennial colonoscopy: - D-COL = 398 D-LYG = 6 (+ 2.6%) - D-COL/D-LYG = 66.3 No efficient 50–85-y screening program compared to 50-75y
Kirstler, 2011 [17]	FOBT	Cohort observed data (no simulations) of FOBT positive individuals with 7 years of follow-up Benefit: observed survival of at least 5 years after the diagnosis of a colorectal neoplasia (advanced adenoma or CRC)	Mean benefit of screening for 15.6% of individuals: - 10% for those with the worst Charlson score - 20% for those with the best score
Lee, 2013 [46]	FOBT	Meta-analysis of survival data observed in CRC screening randomized controlled trials Time Lag to benefit based on MCMC models Life expectancy simulators (eprognosis.com) [47]	Time lags to benefit of absolute risk reduction: - 4.8 years (2.0 to 9.7) needed to prevent one colorectal cancer death for 5000 people screened - 10.3 years (6.0 to 16.4) needed to prevent one colorectal cancer death for 1000 persons screened

Table 3 (continued)

Study	Screening test	Simulation methods, and underlying assumptions	Efficacy based on simulation results
Van Hees, 2014 [43]	FOBT, flexible sigmoidoscopy or colonoscopy in unscreened elderly	Autopsy studies, CRC survival data from SEER program [48] US comorbidities status specific life tables established in 2013 from Medicare population [49]. MISCAN-Colon model calibrated with incidence CRC data observed in the 1975–1979 US SEER program (before introduction of screening), Threshold of willingness to pay: $100,000 /QALY gained	LYG for once-only screening per 1,000 subjects at the age of 80 in subjects with no comorbidity: - Colonoscopy: 52.9 LYG - FIT: 22.5 LYG QALY for once-only FIT screening per 1,000 subjects at the age of 80 according to comorbidity: - Colonoscopy: 46.9 (no comorbidity) to 13.9 (severe comorbidity) - FIT: 19.2 (no comorbidity) to 6.7 (severe comorbidity) Cost-effectiveness cutoff: - No comorbidity 86y - Moderate comorbidity 83y - Severe comorbidity 80y
Van Hees, 2015 [44]	Colonoscopy	SEER program CRC incidence data, MISCAN-Colon model Threshold of willingness to pay: $100,000 /QALY gained	Benefit of screening decreased with age, and harms were greater than benefit for ages between 80 and 85y Screening was cost effective - for individuals without prior screening compared with individuals with prior screening - for individuals without comorbidities compared with individuals with comorbidities
Knudsen, 2016 [45]	Colonoscopy and CT colonography, FOBT, Sigmoidoscopy,	CRC data in US SEER program, US life table. SIM-CRC, MISCAN-Colon and CRC-SPIN models	For persons adequately screened up to age 75 years, additional screening yielded small increases in LYG relative to the increase in colonoscopy burden This suggests that 75 years would be a reasonable age to end screening
Cenin, 2020 [50]	Biennal FIT	MISCAN-Colon	Optimal stopping age for colorectal cancer screening: - 66 years for unhealthy individuals with perfect screening history - 90 years for healthy individuals without prior screening

CRC colorectal cancer, *FIT* Fecal immunochemical test, *FOBT* Fecal occult blood test, *LYG* life year gain, *MCMC* Markov Chain Monte Carlo, *QALY* Quality adjusted life year

life expectancy and fit enough to undergo a potential curative treatment for CRC.

Day et al. reported that 80% of the expected screening benefit is reached when screening ends at 80 years [27, 29]. The great majority of reviews concluded that screening between 75 and 85 years must be decided case by case, considering age, comorbidities and life expectancy [19, 23, 27, 29, 63].

Synthesis of international guidelines

An analysis of international guidelines [66] and ongoing CRC screening programs [11] revealed differences between countries with free-of-charge organized screening programs ending at 75 years old or even earlier, and countries with an opportunistic insurance/copayment screening system based on individual decision-making and extending to as late as 85 years (Table 4).

The European Council recommended screening until the age of 75 [9], and this cut-off is observed in most European countries [67, 68], except for countries that opted for individual-choice screening, which in most cases is not free of charge. In Asia, there tend to be organized screening programs to the age of 75 or 70 years, especially in deprived populations. These often coexist with screening based on individual choice with no upper age limit [74]. In Canadian guidelines, screening after 75 is not recommended but can be discussed [70]. In the USA, CRC screening in the 76–85 age group: 1/ should be an individual decision and can be discussed, according to the NCCN (National Comprehensive Cancer Network), ACS (American Cancer Society) and USPSTF (U.S. Preventive Services Task Force) guidelines, 2/ should be considered for individuals without prior screening, according to the MSTFCC (Multi-Society Task Force on Colorectal Cancer), but is not recommended, according to the ACP (American College of Physicians) guidelines.

Because of the reduction in the expected benefits and the increased risk of colonoscopy-related complications with age [19, 29, 63], most guidelines on screening in subjects aged 75-85y recommend an individual decision based on life expectancy of at least 10 years [20, 21, 28, 70, 73], comorbidities [28, 73] and the history of screening [21, 28, 70, 73].

Discussion

The lack of data on CRC screening in the elderly needs to be addressed. In studies considering patients more than 75 years old, most are just above 75, and the proportion of subjects older than 80, is low. Most of the data come from simulations. Furthermore, the scarce

Table 4 Comparison of upper age limit in ongoing screening programs or guidelines according to countries

	≤ 70 years	≤ 74–75 years	≤ 80 years	≤ 85 years	No upper age limit
Europa [67, 68]	*Finland*, *Georgia*, Greece, *Hungary*, *Italy*, *Kazakhstan*, Malta, *Norway*, *Poland*, *Portugal*, *Slovenia*, *Spain*, *Sweden*, *Turkey*	*Belgium*, *Croatia*, Denmark, *Estonia*, *France*, Iceland, *Ireland*, Israel, Lithuania, Luxembourg, *Netherlands*, *Russian Federation*, *Serbia*, *United Kingdom* European Council guidelines [9]	Monaco, San Marino, Switzerland		Austria, Bosnia and Herzegovina, *Cyprus*, Czech Republic, Germany, Latvia, Republika Sprska, Slovakia Republic
America [11]		USA—ACP guidelines [69]: CRC not recommended as soon as the life expectancy is estimated less than 10 yearsUSA—ACP guidelines [51]: CRC screening not recommended as soon as estimated life expectancy is less than 10 years Canada—CTFPHC guidelines [70]: CRC screening after 75 years is not recommended *but can be discussed*		USA—ACS, USPSTF and NCCN guidelines [28, 71, 72]: *Screening in the 76–85 years age group is an individual decision* USA—MSTFCC guidelines [73]: Screening in the 76–85 years age group considered in individuals without prior screening	
Asia [11, 74]	Hong-Kong, Saudi Arabia [20]	Australia, China, Taiwan			Japan, South Korea, Thailand

Countries in which CRC screening is organized, rather than spontaneous-opportunistic are written in italic

Payment policy: *free of charge, versus $insurance/copayment

In South Korea, on organized free of charge screening program is proposed to most deprived, while others may perform spontaneous screening[97]

available data focus on colonoscopy screening in private healthcare systems that concentrate on individual choice, as in the United States. Most guidelines, especially in countries with a single-payer healthcare system and organized screening, define a fixed-age cut-off for cancer screening at 75 years. In private healthcare systems, extending CRC screening until 80 or even 85y is proposed, with the decision being left to the individual.

The population above 75 years is characterized by its heterogeneity in terms of comorbidities and frailties [75]. It was estimated that a third of the subjects 75 + in the USA have a life expectancy of more than 10 years [76]. The estimated life-expectancy at age 75 years decreases with the number of comorbidities [50, 77]. Multiple chronic conditions not only reduced life expectancy but often increased Disabled Life Expectancy [78].

In France, the organized screening program relies on systematic invitations until the age of 75 years. No specific information is systematically given in the final invitation to inform participants that it is the last invitation. After 75 years the call-recall process simply ends and the centralized laboratory does not analyze screening FITs after 75 years. However, further CRC screening demand occurs after the age of 75 years, from either former regular participants of the organized screening program, or non-participants.. Subjects at high-risk of CRC or with a history of adenoma are excluded from organized screening as they undergo specific regular colonoscopy screening/surveillance. If the last colonoscopy at the age of 75 is normal, this surveillance stops. However, if an adenoma is detected, the follow-up continues and, as in other countries [79], French recommendations do not specify an upper age limit, but stipulate the need to justify the continuation of endoscopic follow-up, taking into account the benefit/risk ratio and, in those aged 80 years or more, a life expectancy of at least 5 years is required [80].

As some subjects over 75 years may benefit from CRC screening, we discussed ways of introducing CRC screening in countries using a FIT-based screening program in the 75–80 age group, based on the following key principles:

- increasing participation in the 50–74 years old population is the priority (the French participation rate is only 30%), including for the last invitation at the age 74,
- continuing screening after 75y should not be systematic,
- decisions to propose screening after 75 years should systematically involve the general practitioner (GP) in charge of the patient, personally, even for former regular participants,
- one-time colonoscopy to end screening does not seem compatible with the French CRC screening program, for several reasons including acceptability, risk and costs.

The organized CRC program could be adapted and continued in the 75-80y age group. However, there is no simple, validated way to identify in the health insurance database individuals unlikely to benefit from screening. Therefore, instead of inviting subjects directly, the invitation could be sent to GPs, who would then select among their patients those who meet screening criteria. Alternatively, CRC screening after 75y could be left to the discretion of the GP, without involving a centralized structure.

The first challenge is to guide the physician in selecting subjects who could benefit from screening, keeping in mind the necessary clinical eligibility of the patient for colonoscopy (including anesthesia) in case of a positive FOBT, together with the risk of overdiagnosis and colonoscopy complications. First, subjects with geriatric syndromes should be excluded from screening. Then, frailty detection tools can be used by GPs, such as the timed up and go test (TUG) or the Gait Speed Test (GST) [81, 82], simpler than the time-consuming Comprehensive Geriatric Assessment (CGA). The Activities of Day Living (ADL) [83] and Instrumental Activities of Day Living (IADL 4 items) [84] scales are also useful, as functional status correlates with overall survival and complications of oncologic treatments [85]. Finally, user-friendly models can estimate life expectancy, expected to be greater than 10y to propose screening.

Among the prognostic indices for community-dwelling older adults identified by the review of Yourman [86], only two can predict outcomes over the coming 9 to 10 years [87, 88]. As these models were built in the United States, they may not be suitable for the French population.

Once elderly people who would benefit from CRC screening have been identified, physicians must adequately communicate with them to explain the choices available. The ability to discuss stopping cancer screening, even in patients younger than 75 years, is an important issue for clinicians [89]. When proposing screening, physicians should raise the issue of the patient's expectations. Even in regular participants (the proportion of whom increases with age [90]), cancer screening after 75 years should not turn into an automatic "routine". The benefit-risk ratio evolves with age. For example, the elderly would be unlikely to benefit from prophylactic removal of adenomas, as this intervention would have a limited impact on CRC incidence and life expectancy [17], whereas the risk associated with colonoscopy increases. Also, the value individuals

place on prolonging life may vary [91]. Some subjects may favor relatively good health in the short term, compared with a prolonged but poorer quality life due to treatment. Information tools should be developed and tested in this population, in order to foster informed decision-making [92].

Should CRC screening be extended to 75 years, the impact on the healthcare system would deserve further attention, and perhaps other health concerns should be prioritized in this specific population. The costs of FIT and their impact on the health care system are far less a matter of concern than is the impact of the colonoscopies induced by this strategy. The availability of colonoscopy resources and the overall costs of these diagnostic procedures need to be verified and would depend on the participation rates in this population. In addition, individuals who regularly participate in CRC screening are those who invest in their health and who would probably have a better life expectancy. The existence of a social gradient in cancer screening participation, and in life expectancy has been well demonstrated [90, 93].

Conclusion

Considering the current literature, there is no Evidence Based Medicine to justify CRC screening beyond 75 years old. The hypotheses established in simulation studies deserve to be verified in prospective studies. There is probably a place for organized mass-screening strategies, with additional exclusion criteria, and/or for opportunistic screening for individuals aged 75–80 years, considering life expectancy and screening history. Screening studies dedicated to the elderly are needed in order to define easy tools and decisional algorithms to underpin practitioners' decisions.

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References

1. Ferlay J, Colombet M, Soerjomataram I, et al. Cancer Incidence and Mortality Patterns in Europe: Estimates for 40 Countries and 25 Major Cancers in 2018. Eur J Cancer. 2018;103:356–87. https://doi.org/10.1016/j.ejca.2018.07.005.
2. Ferlay J, Steliarova-Foucher E, Lortet-Tieulent J, et al. Cancer Incidence and Mortality Patterns in Europe: Estimates for 40 Countries in 2012. Eur J Cancer Oxf Engl 1990. 2013;49(6):1374–403. https://doi.org/10.1016/j.ejca.2012.12.027.
3. Arnold M, Sierra MS, Laversanne M, Soerjomataram I, Jemal A, Bray F. Global patterns and trends in colorectal cancer incidence and mortality. Gut. 2017;66(4):683–91. https://doi.org/10.1136/gutjnl-2015-310912.
4. Defossez G, Le Guyader§Peyrou S, Uhry Z. et al. Estimations Nationales de l'incidence et de La Mortalité Par Cancer En France Métropolitaine Entre 1990 et 2018. Volume 1 – Tumeurs Solides; Santé Publique France: Saint-Maurice, France, 2019; p 372.
5. Cottet V, Jooste V, Bouvier A-M, Michiels C, Faivre J, Bonithon-Kopp C. Time Trends in First-Diagnosis Rates of Colorectal Adenomas: A 24-Year Population-Based Study. Aliment Pharmacol Ther. 2008;27(10):950–9. https://doi.org/10.1111/j.1365-2036.2008.03675.x.
6. Andermann A, Blancquaert I, Beauchamp S, Déry V. Revisiting Wilson and Jungner in the Genomic Age: a review of screening criteria over the past 40 years. Bull World Health Organ. 2008;86(4):317–9. https://doi.org/10.2471/blt.07.050112.
7. Faivre J, Bossard N, Jooste V, et al. Trends in Net Survival from Colon Cancer in Six European Latin Countries: Results from the SUDCAN Population-Based Study. Eur J Cancer Prev. 2017;26:S40–7. https://doi.org/10.1097/CEJ.0000000000000293.
8. Lepage, C.; Bossard, N.; Dejardin, O.; Carmona-Garcia, M. C.; Manfredi, S.; Faivre, J.; GRELL EUROCARE-5 Working Group. Trends in Net Survival from Rectal Cancer in Six European Latin Countries: Results from the SUDCAN Population-Based Study. Eur. J. Cancer Prev. Off. J. Eur. Cancer Prev. Organ. ECP 2017, 26 Trends in cancer net survival in six European Latin Countries: the SUDCAN study, S48–S55. https://doi.org/10.1097/CEJ.0000000000000305.
9. Council of the European Union. Council Recommendation of 2 December 2003 on Cancer Screening (2003/878/EC) 878. 2003.
10. Smith RA, Andrews K, Brooks D, et al. Cancer Screening in the United States, 2016: A Review of Current American Cancer Society Guidelines and Current Issues in Cancer Screening. CA Cancer J Clin. 2016;66(2):96–114. https://doi.org/10.3322/caac.21336.
11. Navarro M, Nicolas A, Ferrandez A, Lanas A. Colorectal Cancer Population Screening Programs Worldwide in 2016: An Update. World J Gastroenterol. 2017;23(20):3632–42. https://doi.org/10.3748/wjg.v23.i20.3632.

12. Welch HG, Black WC. Overdiagnosis in Cancer. J Natl Cancer Inst. 2010;102(9):605–13. https://doi.org/10.1093/jnci/djq099.
13. Marcus, P. M.; Prorok, P. C.; Miller, A. B.; DeVoto, E. J.; Kramer, B. S. Conceptualizing Overdiagnosis in Cancer Screening. J. Natl. Cancer Inst. 2015, 107 (4). https://doi.org/10.1093/jnci/djv014.
14. Mandel JS, et al. The Effect of Fecal Occult-Blood Screening on the Incidence of Colorectal Cancer. The New England Journal of Medicine. 2000;343(22):1603–7.
15. Koïvogui A, Balamou C, Rymzhanova R, et al. Colorectal Cancer Fecal Screening Test Completion after Age 74, Sources and Outcomes in French Program. World J Gastrointest Oncol. 2019;11(9):729–40. https://doi.org/10.4251/wjgo.v11.i9.729.
16. Lin OS, Kozarek RA, Schembre DB, et al. Screening Colonoscopy in Very Elderly Patients: Prevalence of Neoplasia and Estimated Impact on Life Expectancy. JAMA. 2006;295(20):2357–65. https://doi.org/10.1001/jama.295.20.2357.
17. Kistler CE. Long-Term Outcomes Following Positive Fecal Occult Blood Test Results in Older Adults: Benefits and Burdens. Arch Intern Med. 2011;171(15):1344. https://doi.org/10.1001/archinternmed.2011.206.
18. Lieberman D, Ladabaum U, Cruz-Correa M, et al. Screening for Colorectal Cancer and Evolving Issues for Physicians and Patients: A Review. JAMA. 2016;316(20):2135. https://doi.org/10.1001/jama.2016.17418.
19. Alsanea N, Abduljabbar AS, Alhomoud S, Ashari LH, Hibbert D, Bazarbashi S. Colorectal Cancer in Saudi Arabia: Incidence, Survival, Demographics and Implications for National Policies. Ann Saudi Med. 2015;35(3):196–202. https://doi.org/10.5144/0256-4947.2015.196.
20. U.S. Preventive Services Task Force. Screening for Colorectal Cancer: U.S. Preventive Services Task Force Recommendation Statement. Ann. Intern. Med. 2008, 149 (9), 627. https://doi.org/10.7326/0003-4819-149-9-200811040-00243.
21. Aparicio T, Pamoukdjian F, Quero L, Manfredi S, Wind P, Paillaud E. Colorectal Cancer Care in Elderly Patients: Unsolved Issues. Dig Liver Dis. 2016;48(10):1112–8. https://doi.org/10.1016/j.dld.2016.05.011.
22. Quarini C, Gosney M. Review of the Evidence for a Colorectal Cancer Screening Programme in Elderly People. Age Ageing. 2009;38(5):503–8. https://doi.org/10.1093/ageing/afp103.
23. Ko CW, Sonnenberg A. Comparing Risks and Benefits of Colorectal Cancer Screening in Elderly Patients. Gastroenterology. 2005;129(4):1163–70. https://doi.org/10.1053/j.gastro.2005.07.027.
24. Rutter CM, Johnson E, Miglioretti DL, Mandelson MT, Inadomi J, Buist DSM. Adverse Events after Screening and Follow-up Colonoscopy. Cancer Causes Control CCC. 2012;23(2):289–96. https://doi.org/10.1007/s10552-011-9878-5.
25. Ko CW, Riffle S, Michaels L, et al. Serious Complications within 30 Days of Screening and Surveillance Colonoscopy Are Uncommon. Clin Gastroenterol Hepatol Off Clin Pract J Am Gastroenterol Assoc. 2010;8(2):166–73. https://doi.org/10.1016/j.cgh.2009.10.007.
26. Day LW, Walter LC, Velayos F. Colorectal Cancer Screening and Surveillance in the Elderly Patient: *Am*. J Gastroenterol. 2011;106(7):1197–206. https://doi.org/10.1038/ajg.2011.128.
27. Wolf AMD, Fontham ETH, Church TR, et al. Colorectal Cancer Screening for Average-Risk Adults: 2018 Guideline Update from the American Cancer Society: ACS Colorectal Cancer Screening Guideline. CA Cancer J Clin. 2018;68(4):250–81. https://doi.org/10.3322/caac.21457.
28. Day LW, Velayos F. Colorectal Cancer Screening and Surveillance in the Elderly: Updates and Controversies. Gut Liver. 2015;9(2):143–51. https://doi.org/10.5009/gnl14302.
29. Ma W-T, Mahadeva S, Kunanayagam S, Poi PJ-H, Goh K-L. Colonoscopy in Elderly Asians: A Prospective Evaluation in Routine Clinical Practice. J Dig Dis. 2007;8(2):77–81. https://doi.org/10.1111/j.1443-9573.2007.00289.x.
30. Karajeh MA, Sanders DS, Hurlstone DP. Colonoscopy in Elderly People Is a Safe Procedure with a High Diagnostic Yield: A Prospective Comparative Study of 2000 Patients. Endoscopy. 2006;38(3):226–30. https://doi.org/10.1055/s-2005-921209.
31. Salzman B, Beldowski K, de la Paz A. Cancer Screening in Older Patients. Am Fam Physician. 2016;93(8):659–67.
32. Warren, J. L.; Klabunde, C. N.; Mariotto, A. B. et al. Adverse Events after Outpatient Colonoscopy in the Medicare Population. Ann. Intern. Med. 2009, 150 (12), 849–857, W152. https://doi.org/10.7326/0003-4819-150-12-200906160-00008.
33. García-Albéniz X, Hsu J, Bretthauer M, Hernán MA. Effectiveness of Screening Colonoscopy to Prevent Colorectal Cancer Among Medicare Beneficiaries Aged 70 to 79 Years: A Prospective Observational Study. Ann Intern Med. 2017;166(1):18. https://doi.org/10.7326/M16-0758.
34. García-Albéniz X, Hsu J, Bretthauer M, Hernán MA. Screening Colonoscopy to Prevent Colorectal Cancer Among Medicare Beneficiaries Aged 70 to 79 Years. Ann Intern Med. 2017;166(10):758–9. https://doi.org/10.7326/L17-0138.
35. Causada-Calo N, Bishay K, Albashir S, Al Mazroui A, Armstrong D. Association Between Age and Complications After Outpatient Colonoscopy. JAMA Netw Open. 2020;3(6):e208958. https://doi.org/10.1001/jamanetworkopen.2020.8958.
36. Ure T, Dehghan K, Vernava AM, Longo WE, Andrus CA, Daniel GL. Colonoscopy in the Elderly: Low Risk. High Yield Surg Endosc. 1995;9(5):505–8. https://doi.org/10.1007/BF00206836.
37. Yoong KKY. Colonoscopy in the Very Old: Why Bother? Postgrad Med J. 2005;81(953):196–7. https://doi.org/10.1136/pgmj.2004.023374.
38. Rabeneck L, Lewis JD, Paszat LF, Saskin R, Stukel TA. Risk of Proximal and Distal Colorectal Cancer Following Flexible Sigmoidoscopy: a population-based cohort study. Am J Gastroenterol. 2008;103(8):2075–82. https://doi.org/10.1111/j.1572-0241.2008.01932.x.
39. Zafar HM, Harhay MO, Yang J, Armstron K. Adverse Events Following Computed Tomographic Colonography Compared to Optical Colonoscopy in the Elderly. Prev Med Rep. 2014;1:3–8. https://doi.org/10.1016/j.pmedr.2014.08.001.
40. Pendsé DA, Taylor SA. Complications of CT Colonography: A Review. Eur J Radiol. 2013;82(8):1159–65. https://doi.org/10.1016/j.ejrad.2012.04.011.
41. Pickhardt PJ, Correale L, Delsanto S, Regge D, Hassan C. 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;211(1):40–51. https://doi.org/10.2214/AJR.18.19515.
42. Zauber AG, Lansdorp-Vogelaar I, Knudsen AB, Wilschut J, van Ballegooijen M, Kuntz KM. Evaluating Test Strategies for Colorectal Cancer Screening: A Decision Analysis for the U.S. Preventive Services Task Force. Ann Intern Med. 2008;149(9):659. https://doi.org/10.7326/0003-4819-149-9-200811040-00244.
43. van Hees F, Habbema JDF, Meester RG, Lansdorp-Vogelaar I, van Ballegooijen M, Zauber AG. Should Colorectal Cancer Screening Be Considered in Elderly Persons Without Previous Screening?: A Cost-Effectiveness Analysis. Ann Intern Med. 2014;160(11):750. https://doi.org/10.7326/M13-2263.
44. van Hees F, Saini SD, Lansdorp-Vogelaar I, et al. Personalizing Colonoscopy Screening for Elderly Individuals Based on Screening History, Cancer Risk, and Comorbidity Status Could Increase Cost Effectiveness. Gastroenterology. 2015;149(6):1425–37. https://doi.org/10.1053/j.gastro.2015.07.042.
45. Knudsen AB, Zauber AG, Rutter CM, et al. Estimation of Benefits, Burden, and Harms of Colorectal Cancer Screening Strategies: Modeling Study for the US Preventive Services Task Force. JAMA. 2016;315(23):2595. https://doi.org/10.1001/jama.2016.6828.
46. Lee SJ, Boscardin WJ, Stijacic-Cenzer I, Conell-Price J, O'Brien S, Walter LC. Time Lag to Benefit after Screening for Breast and Colorectal Cancer: Meta-Analysis of Survival Data from the United States, Sweden, United Kingdom, and Denmark. BMJ. 2013;346:e8441. https://doi.org/10.1136/bmj.e8441.
47. Cenin, D. R.; Tinmouth, J.; Naber, S. K. et al. Calculation of Stop Ages for Colorectal Cancer Screening Based on Comorbidities and Screening History. Clin. Gastroenterol. Hepatol. Off. Clin. Pract. J. Am. Gastroenterol. Assoc. 2020. https://doi.org/10.1016/j.cgh.2020.05.038.
48. Lee SJ, Leipzig RM, Walter LC. Incorporating Lag Time to Benefit Into Prevention Decisions for Older Adults. JAMA. 2013;310(24):2609. https://doi.org/10.1001/jama.2013.282612.
49. Rutter CM, Johnson EA, Feuer EJ, Knudsen AB, Kuntz KM, Schrag D. Secular Trends in Colon and Rectal Cancer Relative Survival. J Natl Cancer Inst. 2013;105(23):1806–13. https://doi.org/10.1093/jnci/djt299.
50. Cho H, Klabunde CN, Yabroff KR, et al. Comorbidity-Adjusted Life Expectancy: A New Tool to Inform Recommendations for Optimal Screening Strategies. Ann Intern Med. 2013;159(10):667–76. https://doi.org/10.7326/0003-4819-159-10-201311190-00005.
51. Wilt TJ, Harris RP, Qaseem A. High Value Care Task Force of the American College of Physicians. Screening for Cancer: Advice for High-Value

Care from the American College of Physicians. Ann Intern Med. 2015;162(10):718–25. https://doi.org/10.7326/M14-2326.
52. Lansdorp-Vogelaar I, Gulati R, Mariotto AB, et al. Personalizing Age of Cancer Screening Cessation Based on Comorbid Conditions: Model Estimates of Harms and Benefits. Ann Intern Med. 2014;161(2):104. https://doi.org/10.7326/M13-2867.
53. Sonnenberg A. Cost-Effectiveness in the Prevention of Colorectal Cancer. Gastroenterol Clin North Am. 2002;31(4):1069–91. https://doi.org/10.1016/s0889-8553(02)00051-1.
54. Holt PR, Kozuch P, Mewar S. Colon Cancer and the Elderly: From Screening to Treatment in Management of GI Disease in the Elderly. Best Pract Res Clin Gastroenterol. 2009;23(6):889–907. https://doi.org/10.1016/j.bpg.2009.10.010.
55. Institut national du Cancer (INCa). [Medico-Economic Evaluation of Colorectal Cancer Screening / Technical Report, Decision Support]. April 2019.
56. Royce TJ, Hendrix LH, Stokes WA, Allen IM, Chen RC. Cancer Screening Rates in Individuals With Different Life Expectancies. JAMA Intern Med. 2014;174(10):1558. https://doi.org/10.1001/jamainternmed.2014.3895.
57. Walter LC, Lindquist K, Nugent S, et al. Impact of Age and Comorbidity on Colorectal Cancer Screening among Older Veterans. Ann Intern Med. 2009;150(7):465–73. https://doi.org/10.7326/0003-4819-150-7-200904070-00006.
58. Tardieu, E.; Manfredi, S.; Cottet, V.; Faivre, J. Up to what age propose mass screening for colorectal cancer by faecal occult blood test? Analysis of a cohort in a well-defined population; Prague, Czech Republic, 2019; p s-0039–1681624. https://doi.org/10.1055/s-0039-1681624.
59. Dodd RH, Kobayashi LC, von Wagner C. Perceived Life Expectancy and Colorectal Cancer Screening Intentions and Behaviour: A Population-Based UK Study. Prev Med Rep. 2019;16:101002. https://doi.org/10.1016/j.pmedr.2019.101002.
60. Wolf AMD, Schorling JB. Does Informed Consent Alter Elderly Patients' Preferences for Colorectal Cancer Screening?: Results of a Randomized Trial. J Gen Intern Med. 2000;15(1):24–30. https://doi.org/10.1046/j.1525-1497.2000.01079.x.
61. Terret C, Castel-Kremer E, Albrand G, Droz JP. Effects of Comorbidity on Screening and Early Diagnosis of Cancer in Elderly People. Lancet Oncol. 2009;10(1):80–7. https://doi.org/10.1016/S1470-2045(08)70336-X.
62. Tinmouth J, Vella ET, Baxter NN, et al. Colorectal Cancer Screening in Average Risk Populations: Evidence Summary. Can J Gastroenterol Hepatol. 2016;2016:1–18. https://doi.org/10.1155/2016/2878149.
63. Salzman B, University TJ. Cancer Screening in Older Patients. Cancer Screen. 2016;*93* (8):9.
64. Nee J, Chippendale RZ, Feuerstein JD. Screening for Colon Cancer in Older Adults: Risks, Benefits, and When to Stop. Mayo Clin Proc. 2020;95(1):184–96. https://doi.org/10.1016/j.mayocp.2019.02.021.
65. Pasetto LM, Monfardini S. Colorectal Cancer Screening in Elderly Patients: When Should Be More Useful? Cancer Treat Rev. 2007;33(6):528–32. https://doi.org/10.1016/j.ctrv.2007.04.004.
66. Bénard F, Barkun AN, Martel M, von Renteln D. Systematic Review of Colorectal Cancer Screening Guidelines for Average-Risk Adults: Summarizing the Current Global Recommendations. World J Gastroenterol. 2018;24(1):124–38. https://doi.org/10.3748/wjg.v24.i1.124.
67. Altobelli E, D'Aloisio F, Angeletti PM. Colorectal Cancer Screening in Countries of European Council Outside of the EU-28. World J Gastroenterol. 2016;22(20):4946. https://doi.org/10.3748/wjg.v22.i20.4946.
68. Altobelli E, Rapacchietta L, Marziliano C, Campagna G, Profeta V, Fagnano R. Differences in Colorectal Cancer Surveillance Epidemiology and Screening in the WHO European Region. Oncol. Lett. 2018. https://doi.org/10.3892/ol.2018.9851.
69. Lin JS, Piper MA, Perdue LA, et al. Screening for Colorectal Cancer: Updated Evidence Report and Systematic Review for the US Preventive Services Task Force. JAMA. 2016;315(23):2576. https://doi.org/10.1001/jama.2016.3332.
70. Canadian Task Force on Preventive Health Care. Recommendations on Screening for Colorectal Cancer in Primary Care. Can Med Assoc J. 2016;188(5):340–8. https://doi.org/10.1503/cmaj.151125.
71. Provenzale D, Gupta S, Ahnen DJ, et al. NCCN Guidelines Insights: Colorectal Cancer Screening, Version 1.2018. J Natl Compr Cancer Netw. 2018;16(8):939–49. https://doi.org/10.6004/jnccn.2018.0067.
72. Jung M. National Cancer Screening Programs and Evidence-Based Healthcare Policy in South Korea. Health Policy Amst Neth. 2015;119(1):26–32. https://doi.org/10.1016/j.healthpol.2014.08.012.
73. Rex DK, Boland CR, Dominitz JA, et al. Colorectal Cancer Screening: Recommendations for Physicians and Patients From the U.S. Multi-Society Task Force on Colorectal Cancer. Gastroenterolog. 2017;153(1):307–23. https://doi.org/10.1053/j.gastro.2017.05.013.
74. Sano Y, Byeon J-S, Li X-B, et al. Colorectal Cancer Screening of the General Population in East Asia. Dig Endosc Off J Jpn Gastroenterol Endosc Soc. 2016;28(3):243–9. https://doi.org/10.1111/den.12579.
75. Rolland Y, Benetos A, Gentric A, et al. Frailty in older population: a brief position paper from the French society of geriatrics and gerontology. Geriatr Psychol Neuropsychiatr Vieil. 2011;9(4):387–90. https://doi.org/10.1684/pnv.2011.0311.
76. Schonberg MA, Breslau ES, Hamel MB, Bellizzi KM, McCarthy EP. Colon Cancer Screening in U.S. Adults Aged 65 and Older According to Life Expectancy and Age. J Am Geriatr Soc. 2015;63(4):750–75. https://doi.org/10.1111/jgs.13335.
77. DuGoff EH, Canudas-Romo V, Buttorff C, Leff B, Anderson GF. Multiple Chronic Conditions and Life Expectancy: A Life Table Analysis. Med Care. 2014;52(8):688–94. https://doi.org/10.1097/MLR.0000000000000166.
78. Laditka JN, Laditka SB. Associations of Multiple Chronic Health Conditions with Active Life Expectancy in the United States. Disabil Rehabil. 2016;38(4):354–61. https://doi.org/10.3109/09638288.2015.1041614.
79. Maratt JK, Calderwood AH. Colorectal Cancer Screening and Surveillance Colonoscopy in Older Adults. Curr Treat Options Gastroenterol. 2019;17(2):292–302. https://doi.org/10.1007/s11938-019-00230-9.
80. Haute Autorité de Santé. [Post Polypectomy Surveillance Protocole]. 2013.
81. Mongiat-Artus, P, Paillaud, E, Albrand G, Caillet P, Neuzillet Y. [Evaluation of the elderly patient with cancer]. Progres En Urol. J. Assoc. Francaise Urol. Soc. Francaise Urol. 2019, 29 (14), 807–827. https://doi.org/10.1016/j.purol.2019.08.279.
82. Redín-Sagredo, M. J.; Aldaz Herce, P.; Casas Herrero, A.; Gutiérrez-Valencia, M.; Martínez-Velilla, N. [Heterogeneity amongst different diagnostic tools in frailty screening]. An. Sist. Sanit. Navar. 2019, 42 (2), 169–178. https://doi.org/10.23938/ASSN.0642.
83. Katz S, Ford AB, Moskowitz RW, Jackson BA, Jaffe MW. Studies of illness in the aged. The index of adl: a standardized measure of biological and psychosocial function. JAMA. 1963;185:914–9. https://doi.org/10.1001/jama.1963.03060120024016.
84. Lawton MP, Brody EM. Assessment of Older People: Self-Maintaining and Instrumental Activities of Daily Living. Gerontologist. 1969;9(3):179–86.
85. Soto-Perez-de-Celis E, Li D, Yuan Y, Lau YM, Hurria A. Functional versus Chronological Age: Geriatric Assessments to Guide Decision Making in Older Patients with Cancer. Lancet Oncol. 2018;19(6):e305–16. https://doi.org/10.1016/S1470-2045(18)30348-6.
86. Yourman LC, Lee SJ, Schonberg MA, Widera EW, Smith AK. Prognostic Indices for Older Adults: A Systematic Review. JAMA. 2012;307(2):182. https://doi.org/10.1001/jama.2011.1966.
87. Schonberg MA, Davis RB, McCarthy EP, Marcantonio ER. External Validation of an Index to Predict Up to 9-Year Mortality of Community-Dwelling Adults Aged 65 and Older: EXTERNAL VALIDATION OF MORTALITY INDEX. J Am Geriatr Soc. 2011;59(8):1444–51. https://doi.org/10.1111/j.1532-5415.2011.03523.x.
88. Cruz M, Covinsky K, Widera EW, Stijacic-Cenzer I, Lee SJ. Predicting 10-Year Mortality for Older Adults. JAMA. 2013;309(9):874. https://doi.org/10.1001/jama.2013.1184.
89. Schoenborn NL, Boyd CM, Lee SJ, Cayea D, Pollack CE. Communicating About Stopping Cancer Screening: Comparing Clinicians' and Older Adults' Perspectives. Gerontologist. 2019;59(Supplement_1):S67–76. https://doi.org/10.1093/geront/gny172.
90. Pornet C, Denis B, Perrin P, Gendre I, Launoy G. Predictors of Adherence to Repeat Fecal Occult Blood Test in a Population-Based Colorectal Cancer Screening Program. Br J Cancer. 2014;111(11):2152–5. https://doi.org/10.1038/bjc.2014.507.
91. Sheinfeld Gorin S, Gauthier J, Hay J, Miles A, Wardle J. Cancer Screening and Aging: Research Barriers and Opportunities. Cancer. 2008;113(12 Suppl):3493–504. https://doi.org/10.1002/cncr.23938.

92. Lewis CL, Golin CE, DeLeon C, et al. A Targeted Decision Aid for the Elderly to Decide Whether to Undergo Colorectal Cancer Screening: Development and Results of an Uncontrolled Trial. BMC Med Inform Decis Mak. 2010;10:54. https://doi.org/10.1186/1472-6947-10-54.
93. Pornet C, Dejardin O, Morlais F, Bouvier V, Launoy G. Socioeconomic Determinants for Compliance to Colorectal Cancer Screening. A Multilevel Analysis. J Epidemiol Community Health. 2010;64(4):318–24. https://doi.org/10.1136/jech.2008.081117.

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