World J Surg (2019) 43:2077–2085
https://doi.org/10.1007/s00268-019-04978-0

ORIGINAL SCIENTIFIC REPORT

Years of Life Lost for Older Patients After Colorectal Cancer Diagnosis

Federico Mazzotti[1,2] · Alessandro Cucchetti[2] · Yvette H. M. Claassen[3] · Amanda C. R. K. Bos[4] · Esther Bastiaannet[3,5] · Giorgio Ercolani[2] · Jan Willem T. Dekker[1]

Published online: 12 March 2019
© Société Internationale de Chirurgie 2019

Abstract

Background An aging population combined with an increased colorectal cancer (CRC) incidence in the older population will increase its prevalence in the elderly, questioning how many years of life are lost (YLLs) in these patients.

Patients and methods Data from 32,568 Dutch CRC patients ≥ 80 years were used to estimate the number of YLLs after diagnosis, using a reference age-, sex- and year-of-onset-matched cohort derived from national life tables. YLLs were additionally adjusted by comorbidities. Number needed to treat (NNT) was used as measure of surgical effect size.

Results Surgery was applied in 74.9% of patients leading to 1.3 YLLs, being superior in 86.1% of cases with respect to alternative therapies (YLLs 4.8 years) and resulting in a number of two patients needed to operate to achieve one positive outcome. YLLs and NNTs depended on CRC stage, patient' age and comorbidities. For Stage I–II patients in the best clinical conditions (80–85 years without comorbidities), YLLs increased up to 4.1 years after surgery and up to 8.8 years without surgery (NNT 3). For Stage III patients, the NNT of surgery varied between 2 when they were in the best clinical conditions and 4 when they were older with high comorbidities. In Stage IV patients, the NNT ranged between 6 and 31.

Conclusions YLLs represents a novel approach to evaluate CRC prognosis. Stage I–III surgical patients can have a life expectancy similar to that of general population, being the NNT of surgery reasonably small compared with alternatives. Personalized comorbidity data are needed to confirm present findings.

Federico Mazzotti and Alessandro Cucchetti have contributed equally to the present work.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00268-019-04978-0) contains supplementary material, which is available to authorized users.

✉ Federico Mazzotti
mazzottifederico@gmail.com

1 Department of Surgery, Reinier de Graaf Gasthuis, Delft, The Netherlands

2 Department of Medical and Surgical Science — DIMEC, Alma Mater Studiorum - University of Bologna, Bologna, Italy

3 Department of Surgical Oncology, Leiden University Medical Center, Leiden, The Netherlands

4 Department of Research, Netherlands Comprehensive Cancer Organisation (IKNL), Utrecht, The Netherlands

5 Department of Medical Oncology, Leiden University Medical Center, Leiden, The Netherlands

Introduction

The Netherlands is currently one of the European countries suffering from the highest incidence of colorectal cancer (CRC), which is of about 40 cases per 100,000 inhabitants, and the cause of death of approximately 4800 people each year [1, 2]. Incidence rises steeply from around the age of fifty and reaches the highest rates in septu- and octogenarians [2]. Furthermore, Dutch life expectancy from birth has progressively increased in the last decade up to more than 80 years to date [3]. An aging population, combined with an increased CRC incidence in the older population, will significantly increase the prevalence of CRC in the old-olds and the oldest-olds in the foreseeable future [4].

Colonic resection in the elderly can result in increased morbidity and mortality, and as age increases, the less likely patients are to undergo such potentially curative treatment [5–8]. Nevertheless, a careful selection of older patients, as well as improvements in surgical and nonsurgical care, can provide short- and middle-term outcomes similar to that of younger patients [9]. Long-term results inevitability remain ambiguous, as the main consequence of the unavoidable age-related mortality, making a reliable long-term comparison between younger and older patients outcomes unreliable with respect to overall survival [10]. In this regard, relative survival can help in understanding the true benefit achievable from surgical and nonsurgical therapies for CRC, by taking into account the age at which the deaths occur [11, 12].

Relative survival provides an estimate of population-level effect, but can be difficult to interpret for individual patients. For a better understanding of the impact that CRC diagnosis and subsequent treatment options have for them, potential years of life lost (YLLs) could be useful [11, 13]. Potential years of life lost is a measure of relative survival and represents the average number of years a person would have lived if he or she had not died prematurely due to the cancer under study [12, 14].

The aim of the present study was to assess potential YLLs due to CRC in a nationwide cohort of patients aged 80 years or more. Relationships with sex, age, tumor burden and especially surgical resection were explored.

Methods

Study population

All patients aged $\geq$ 80 years diagnosed with CRC between 2001 and 2015 were selected from the Netherlands Cancer Registry (Intergraal Kankercentrum Nederland—IKNL). The registry contains information on all newly diagnosed malignancies in the Netherlands [15]. Primary treatment is coded in the sequence of administration, and patients are staged according to the International Union Against Cancer (UICC) classification [16]. Location and morphology are coded according to the International Classification of Diseases for Oncology [17]. Since the Netherlands cancer registry registers anonymous population data, no written informed consent was required.

Estimation of lifespan and years of life lost

The estimation of residual lifespan after CRC diagnosis relies on the concept that these patients would die from causes directly related to the oncological disease in addition to the common causes experienced by the age- and sex-matched general population, with a *constant excess hazard* for the CRC cohort [18, 19]. An age-, sex- and year-of-diagnosis-matched reference population was generated from Dutch life tables obtained from the Global Health Observatory data repository using the Monte Carlo method described by Hwang and Wang [18, 20]. Using this approach, it was possible to estimate the lifespan after tumor diagnosis of the CRC cohort with a time-horizon set at 20 years (Fig. 1) [21, 22]. Additional details are reported in the Supporting information. Once the post-diagnosis lifespan was obtained, YLLs were calculated as the difference in the area between the mean survival curves of the CRC cohort and that of the reference population. The ISQoL (integration of survival and quality of life) package for R project was used for all the calculations.

In addition, since the IKNL database did not provide adequate personalized data which would be essential at an individual patient level, such as comorbidities, performance status, anesthetic risks and/or symptoms related to cancer, the methodology proposed by Cho et al. [23] was here adopted, which simulated how YLLs would have changed in the absence, or presence, of different degrees of comorbidities (Supporting information). This approach was necessary since comorbidities would significantly affect prognosis, treatment options and, finally, YLLs.

Outcome measures

Differences in YLLs observed in the analyzed subgroups were here reported applying effect size measures. In particular, standardized differences (*d* value), the common language effect size (CL) and the number needed to treat (NNT) were calculated [24–26]. From a clinical perspective, a low number of YLLs mean that the diagnosis of CRC did not grossly change the life expectancy of the patient after a specific treatment. NNT returns here the probability of success of surgery, meaning that 1 out of *x* patients would experience the benefit of colonic

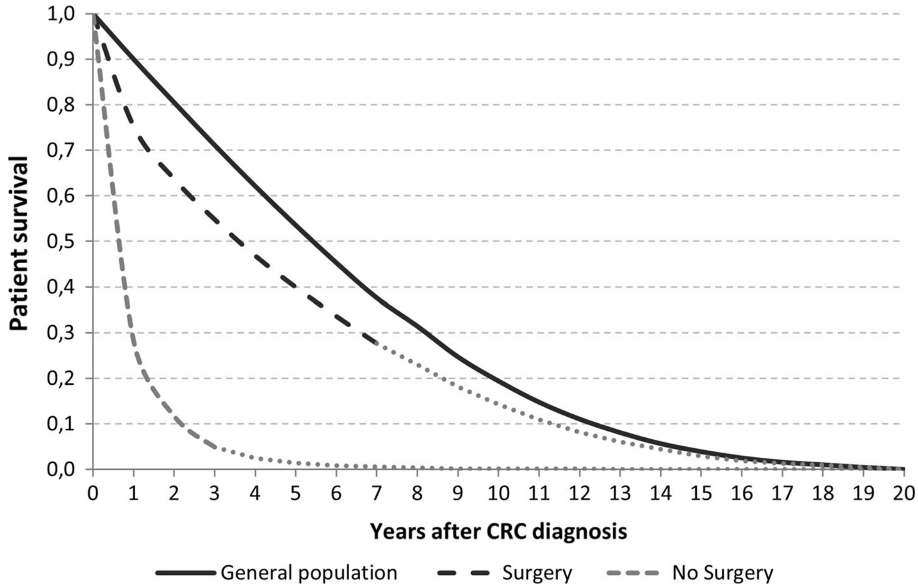

Fig. 1 Survival differences between patients with CRC and age-, year- and sex-matched reference population. Dotted lines indicates life expectancy extrapolation

resection, whereas in the remaining $x - 1$, surgical and nonsurgical therapies would gone identical. Please refer to Supporting information for a detailed description.

Results

Baseline characteristics

The study population included 32,568 CRC patients aged 80 years or more, diagnosed between 2001 and 2015. Clinical characteristics are detailed in Table 1. Of them, 74.9% underwent surgery (n = 24,381). Most of patients had a Stage II–III CRC (60.0%), being the ascending and transverse colon the most frequent tumor sites (43.1%). Tumor stage was not available in 29.7% of nonsurgical patients. Chemotherapy and radiotherapy were seldom adopted either as neo-adjuvant/adjuvant or stand-alone therapies (5.1% and 11.8%, respectively). The median follow-up was 7 years, and the mean patient survival was of 3.9 years (median 2.0).

The mean survival of surgical patients was 4.8 years (SE 0.40), and that of nonsurgical patients was 10 months (SE 0.17). The 1-year survival after surgery was 75.1%. Nonsurgical patients more frequently suffered from Stage IV disease (d value 2.157) and rectal cancer (d value 1.024) in comparison with surgical ones. (Table 1).

Estimation of years of life lost

Considering all patients, the number of potential YLLs was estimated to be 2.2 years (SE 0.03, Table 2). Gender had no influence on YLLs, but the older patients were more frequently female (Fig. 2a). Tumor location was not associated with differences in YLLs (d value < 0.5). As expected, tumor stage was the main determinant of YLLs, but the magnitude was small between Stage I (YLLs = 0.3 years) and Stage II (0.9 years). Stage III showed a considerable higher YYLs compared with Stage I and Stage II (YLLs = 2.4 vs 0.9 in Stage II and 0.2 in Stage I).

In the whole study population, the number of YLLs was lower in surgical patients with respect to nonsurgical ones (d value 1.371; superiority 86.1%), returning a calculated NNT of two patients to achieve one positive additional outcome. The older the patients were, the more likely they were not to undergo surgery, which benefits, however, would remain large even if reduced with advancing age (Fig. 2b).

Years of life lost by age and stage

Surgical Stage I–III patients had a lower YLLs when aged between 80 and 85 years (Table 3) with probabilities of superiority always >75% and NNTs between 2 and 3. For similar older patients (86–90+ years), superiority decreased to 60–70%, with an increment in the NNT values up to 3 and 6. For the Stage IV, the probability of surgery of being superior to no surgery decreased to 56.7% in patients aged 80–85 years (NNT 8) and to 54.9% in patients aged 86–90+ years (NNT 15).

Results after the adjustment of life expectancy of the reference cohort are detailed in Table 4. Operating in Stages I–III would return small NNT values, between 2 and 4 regardless of comorbidities. The number of YLLs progressively decreased with increased comorbidities severity in both surgical and nonsurgical patients. Conversely,

Table 1 Characteristics of the study population of CRC patients aged 80 years and above included in the present analysis

Features	All patients (n = 32,568)	Surgery (n = 24,381)	No surgery (8187)	d value
Age				
Mean (years; SD)	84.2 (3.5)	83.8 (3.3)	85.1 (3.9)	0.360
Median (years; IQR)	83.0 (81–86)	83.0 (81–86)	84.0 (82–88)	Nr
Year of diagnosis				
2001–2005	7626 (23.4%)	5657 (23.2%)	1969 (24.1%)	0.050
2006–2010	12,224 (37.5%)	9396 (38.5%)	2828 (34.5%)	0.173
2011–2015	12,718 (39.1%)	9328 (38.3%)	3390 (41.4%)	0.129
Gender				
Female	17,941 (55.1%)	13,463 (55.2%)	4478 (54.7%)	0.020
Male	14,627 (44.9%)	10,918 (44.8%)	3709 (45.3%)	Nr
Tumor stage				
Stage I	4580 (14.1%)	4268 (17.5%)	312 (3.8%)	1.514
Stage II	11,207 (34.4%)	10,163 (41.7%)	1044 (12.8%)	1.629
Stage III	8323 (25.6%)	7618 (31.2%)	705 (8.6%)	1.541
Stage IV	5962 (18.3%)	2267 (9.3%)	3695 (45.1%)	2.157
Not available	2496 (7.7%)	65 (0.3%)	2431 (29.7%)	Nr
Tumor location				
Ascending + transverse	14,027 (43.1%)	11,513 (47.2%)	2514 (30.7%)	0.714
Descending until sigmoid	1899 (5.8%)	1514 (6.2%)	385 (4.7%)	0.291
Sigmoid or sigma–rectum	8737 (26.8%)	6764 (27.7%)	1973 (24.1%)	0.188
Rectum	7213 (22.1%)	4222 (17.3%)	2991 (36.5%)	1.024
Multiple sites	334 (1.0%)	224 (0.9%)	110 (1.3%)	0.368
Not available	358 (1.1%)	144 (0.6%)	214 (2.6%)	Nr
Therapy*				
Chemotherapy	1648 (5.1%)	927 (3.8%)	721 (8.8%)	0.856
Radiotherapy	3841 (11.8%)	2584 (10.6%)	1257 (15.4%)	0.427
Overall survival				
1-year (95% C.I.)	64.6% (64.0–65.2)	76.0% (75.4–76.6)	30.4% (29.4–31.4)	2.315
3-year (95% C.I.)	42.2% (41.6–42.8)	55.4% (54.8–56.0)	5.3% (4.7–5.9)	3.371
5-year (95% C.I.)	30.5% (29.9–31.1)	40.1% (39.5–40.7)	1.5% (1.1–1.9)	3.028

Effect size values expressed as d values refer to comparisons of one group against the reference: values ~ 0.2 indicated small differences; values ~ 0.5 indicated medium differences, and values ~ 0.8 indicated large differences

Nr not reported

*Either neo-adjuvant and/or adjuvant after surgery or stand-alone for nonsurgical patients

operating in Stage IV disease returned relative low NNT value of 6 in patients aged 80–85 years without comorbidities, whereas in all the other instances, NNT values ranged between 10 and 31.

Discussion

The impact of age on postoperative outcome after colorectal surgery is an open debate. Postoperative mortality and morbidity are likely to increase with aging. Although conditional relative survival for elderly is similar to that for younger patients [27], large differences remain in absolute survival. In order to fully capture the survival benefit obtainable from colonic resection, in relationship with aging, YLLs would be an appropriate outcome measure to apply.

We here found that overall, the diagnosis of CRC returns an average YLLs of 2.2 years over the entire life span from birth (Table 2). Considering that the average age was of 84 years, this means that CRC patients lost <3% of their entire life span in comparison with the general

Table 2 Estimation of the residual life expectancy and numbers of years of life lost (YLLs) in comparison with the reference cohort. Groups are ordered in decreasing YLLs values

	Age	Life expectancy	YLLs	*d* value	CL
All patients (*n* = 32,568)	84.2 (0.02)	3.8 (0.01)	2.2 (0.03)	–	–
Gender					
Female (*n* = 17,941)	84.5 (0.03)	4.1 (0.06)	2.3 (0.06)	Ref.	Ref.
Male (*n* = 14,627)	83.8 (0.03)	3.4 (0.05)	2.0 (0.05)	0.040	51.2%
Age groups					
80–82 y (*n* = 12,895)	81.0 (0.07)	4.5 (0.07)	2.9 (0.07)	Ref.	Ref.
83–85 y (*n* = 9694)	84.0 (0.08)	3.8 (0.06)	2.2 (0.06)	0.100	52.9%
86–89 y (*n* = 7169)	87.2 (0.01)	3.0 (0.05)	1.6 (0.05)	0.195	55.8%
90 + y (*n* = 2810)	91.8 (0.04)	2.0 (0.05)	1.1 (0.05)	0.247	60.4%
Year of diagnosis					
2001–2005 (*n* = 7626)	84.2 (0.03)	3.3 (0.06)	2.3 (0.06)	Ref.	Ref.
2006–2010 (*n* = 12,224)	84.2 (0.03)	3.8 (0.06)	2.2 (0.06)	0.288	58.2%
2011–2015 (*n* = 12,718)	84.1 (0.03)	4.2 (0.07)	2.1 (0.07)	0.346	59.9%
Tumor stage					
Stage IV (*n* = 5962)	83.8 (0.04)	0.9 (0.02)	5.2 (0.03)	Ref.	Ref.
Stage III (*n* = 8323)	84.0 (0.04)	3.7 (0.07)	2.4 (0.07)	0.583	66.9%
Stage II (*n* = 11,207)	84.1 (0.03)	5.1 (0.05)	0.9 (0.05)	1.052	79.3%
Stage I (*n* = 4580)	83.7 (0.05)	5.9 (0.08)	0.3 (0.06)	1.482	84.4%
Tumor location					
Rectum (*n* = 7213)	84.2 (0.04)	3.4 (0.06)	2.5 (0.06)	Ref.	Ref.
Colon–Sigma (*n* = 25,355)	84.1 (0.02)	3.9 (0.04)	2.1 (0.04)	0.079	53.0%
Therapy					
No surgery (*n* = 8187)	85.1 (0.04)	0.8 (0.01)	4.8 (0.02)	Ref.	Ref.
Surgery (*n* = 24,381)	83.8 (0.02)	4.8 (0.04)	1.3 (0.04)	1.371	86.1%

Age, survivals and YLLs are reported in years as means and standard errors

Effect size values expressed as *d* values refer to comparisons of one group against the reference: values ~ 0.2 indicated small differences; values ~ 0.5 indicated medium differences, and values ~ 0.8 indicated large differences

CL is called "probability of superiority" and gives here the probability that a person of a specific group will have lower YLLs than a person from the control group. This measure range between 50% = equal chances to 100% = all patients will have lower YLLs than the control group

Information regarding tumor stage was not available for 2496 patients (7.7% of the whole study population). Tumor location did not include 692 cases (2.1% of the whole study population) with multiple CRC sites or unavailable data

population. The benefit of surgery was large in comparison with therapeutic alternatives, with a probability of success of 86.1%, modified by further aging and tumor stage (Table 3). Patients submitted to surgery for Stage I cancer practically experience the same life expectancy of general population (YLLs 0.2), and this figure was also valid for Stage II in the oldest-olds. This means that for these patients, surgery can provide the "statistical cure" and the low NNT values (data surely useful for the informed consent process as well as the team discussion when planning the treatment) reinforce such quality [28]. For the Stage III, NNT values only marginally increased. In Stage IV patients, surgery is recommended only in symptomatic or highly selected patients [29–31]. This aspect becomes more problematic in old patients. The expected residual life expectancy is low after surgery and slightly above those expectable from the nonsurgical approach. A survival benefit could be obtained only in a small proportion of these patients as defined by high NNT values; thus, present results suggest that colonic resection can be considered a "healing" therapy in elderly Stage I–III patients [32].

Stage was not available in 7.7% of the cohort, and most of them were not submitted to surgery accounting for almost one-third of nonsurgical patients. This reflects the management of elderly patients with CRC in which probably a large part of them did not complete a staging because considered not suitable for surgery. This aspect underlines the ethical issue when deciding to operate or not old patients because the gain of surgery in these patients is, as expectable, lower than that of the younger counterpart.

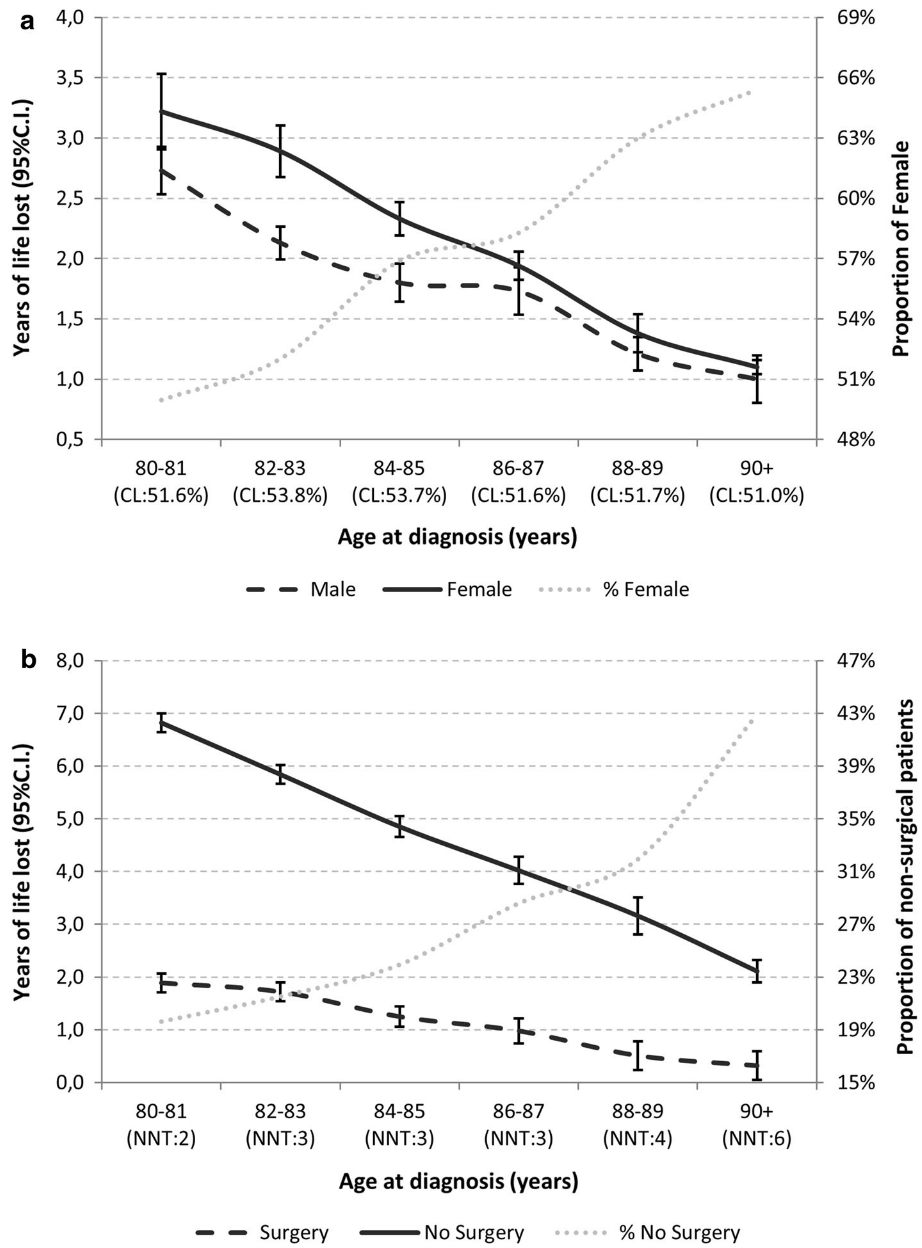

Fig. 2 **a** YLLs in relationship with sex. CL indicates probability of superiority and range between 50% (= equal probabilities) to 100%. **b** YLLs in relationship with surgery versus no surgery. NNT indicates the number needed to treat in order to obtain one more favorable outcome from surgery

As depicted in Fig. 2b, in the present study, the older patients become the less likely they are to undergo surgery [5, 6]. Comorbidity represents the main concern to operate on these patients. It was reported that cardiopulmonary comorbidities increase from 36% in CRC patients aged <70 years, up to 55% in patients aged 85+ years. Likewise, ASA classification 3–4 increases from 23 to 55%, respectively [7]. Accordingly, surgical patients in the present series may be those without significant comorbidities and fit for surgery, while nonsurgical patients may be those with important comorbidities. These aspects not only introduce a selection bias, but also a potential "survivor treatment bias" where patients not healthy enough for surgery not only are less likely to undergo surgery but also are more likely to experience early mortality after diagnosis. We need to early acknowledge that, as previously stated, the current dataset did not provide personalized information which could be of extreme interest for the present study aim. In particular, personalized data about comorbidities, performance status, physiology score and symptoms related to cancer leading to eventual emergency surgery (such as bleeding or obstruction) would add that information useful to surpass selection and survivor treatment biases. We were thus forced to handle comorbidities by exploring different clinical scenarios, in a sensitivity analysis, as reported in Table 4 to minimize these biases.

Table 3 Estimation of the residual life expectancy and numbers of years of life lost (YLLs) in comparison with the reference cohort

Features	Surgery		No surgery		CL (%)	NNT
	Life expectancy	YLLs	Life expectancy	YLLs		
80–85 years						
Stage I (n = 3240/160)	6.6 (0.12)	0.2 (0.12)	2.2 (0.09)	4.4 (0.11)	79.3	2
Stage II (n = 7249/575)	5.6 (0.15)	1.2 (0.07)	1.5 (0.06)	5.2 (0.12)	77.0	2
Stage III (n = 5938/409)	4.1 (0.08)	2.7 (0.07)	1.0 (0.09)	5.8 (0.10)	73.3	3
Stage IV (n = 1687/2611)	1.5 (0.05)	5.3 (0.07)	0.8 (0.01)	6.0 (0.06)	56.7	8
86–90 + years						
Stage I (3942/691)	4.1 (0.15)	0.2 (0.15)	1.6 (0.12)	2.2 (0.14)	68.7	3
Stage II (2914/469)	3.9 (0.09)	0.3 (0.11)	1.4 (0.12)	2.6 (0.14)	66.4	4
Stage III (2809/296)	2.9 (0.12)	1.4 (0.12)	1.2 (0.09)	2.9 (0.11)	61.4	6
Stage IV (580/296)	1.3 (0.12)	3.0 (0.12)	0.8 (0.09)	3.3 (0.11)	54.9	15

Life expectancies and YLLs are reported in years as means and standard errors (SE). This analysis did not include 2496 patients without available assessment of tumor stage (7.7% of the whole study population)

Number needed to treat (NNT) here refers to the number of patients needed to be operated to obtain one additional patient who will achieve a survival benefit from surgery in comparison with no surgery, having the YLLs as the endpoint measure. (e.g., a NNT = 5 means that one patient out of six operated will achieve a survival benefit, whereas the other five will experience the same outcome of avoiding surgery)

As a result, in Stages I–III, we did not observe a different surgical benefit when stratifying for comorbidities, simply because YLLs decreased in parallel, with increased comorbidities severity, in both surgical and nonsurgical patients so that the anticipated NNT was practically unaffected. This is obviously a sensitivity analysis which cannot completely avoid selection and survivor treatment biases but surely mitigate them.

In the present series, a low utilization of chemotherapy (5.1%) and of radiotherapy (11.8%) was observed. Previous experiences showed that the probability of receiving chemotherapy decreases from about 60–70% in patients aged 65–74 years, to about 15–20% in patients aged 75+ years [33–35]. *C*onsidering that the current study population is formed by patients aged 80+, the present finding of 5.1% receiving chemotherapy is expectable. Similarly, a study conducted on the Netherlands Cancer Registry showed that radiotherapy utilization, in the preoperative setting of rectal cancer, sharply decreased from about 50–70% in patients aged <75 years to about 10–30% in patients aged 80+ years [15]. Thus, when interpreting the present findings, in terms of YLLs, the nonsurgical scenario was mainly represented here by the best supportive cares. It should also be noted that unfit elderly patients probably do not receive chemotherapy, but present results also reflect the fact that some fit elderly patients may currently be under-treated [36]. Some authors recently provided some evidence of a survival benefit of chemotherapy and radiotherapy that also applies to the elderly [35]. In particular, the introduction of less toxic and more manageable chemotherapeutic regimens will produce some survival benefit in the future in both surgical and nonsurgical older patients [36]. Additional analyses on YLLs after chemotherapy and radiotherapy would represent another additional field of research.

The present study has some limitations mostly due to the retrospective nature and the intrinsic limitation common to all cancer registries as previously outlined [7, 15] Furthermore, this study shows bias due to confounding by indication, as often occurs in the majority of observational studies [37]. This results in a bias when comparing outcomes between surgically and nonsurgically treated patients, and direct comparisons can result in some overestimation of treatment efficacy. As previously stated, treatment allocation is usually the result of a specific reason which cannot be corrected and can be responsible for part of the large differences found in YLLs between surgical and nonsurgical patients. The main potential limitation remains the absence of comorbidity data in the present study population. In our approach, we adjusted reference life tables for severity of potential comorbidities, but we were unable to obtain patient comorbidities necessary to perfectly match them. In this regard, the most likely and comparable scenario would be the one where low/intermediate comorbidities are present, and this scenario grossly correspond to the unadjusted life tables, as previously suggested by developers of this epidemiological technique [23]. Despite potential limitations, the main strengths of this study are the very large cohort of very old CRC patients, the novel approach to determine the impact of CRC diagnosis and subsequent treatment in very old patients and the NNT measure which could aid in a shared

Table 4 Estimation of potential years of life lost (YLLs) in relationship with age and tumor stage and in comparison with the reference cohort adjusted by comorbidities

Features	Surgery YLLs (SE)	No surgery YLLs (SE)	CL (%)	NNT
80–85 years				
No comorbidities				
Stages I–II	4.1 (0.10)	8.8 (0.10)	72.5	3
Stage III	5.9 (0.06)	9.2 (0.09)	80.8	2
Stage IV	8.7 (0.09)	9.7 (0.06)	58.1	6
Low/intermediate comorbidities				
Stages I–II	1.0 (0.08)	5.4 (0.11)	74.6	3
Stage III	2.9 (0.06)	6.0 (0.08)	80.0	2
Stage IV	5.7 (0.10)	6.4 (0.10)	54.3	12
High comorbidities				
Stages I–II	0.2 (0.08)	4.2 (0.10)	73.1	3
Stage III	1.4 (0.06)	4.4 (0.09)	78.6	2
Stage IV	4.4 (0.10)	4.8 (0.09)	52.6	19
86–90 + years				
No comorbidities				
Stages I–II	1.9 (0.08)	4.9 (0.10)	74.0	2
Stage III	3.3 (0.08)	5.2 (0.11)	70.9	3
Stage IV	5.1 (0.10)	5.6 (0.10)	55.1	10
Low/intermediate comorbidities				
Stages I–II	0.6 (0.09)	2.9 (0.09)	68.5	3
Stage III	1.4 (0.10)	3.1 (0.08)	67.5	4
Stage IV	3.3 (0.10)	3.6 (0.10)	53.1	17
High comorbidities				
Stages I–II	0.2 (0.09)	2.3 (0.09)	66.5	4
Stage III	1.2 (0.08)	2.4 (0.10)	64.1	4
Stage IV	2.9 (0.15)	3.1 (0.10)	51.6	31

The life expectancy of the reference cohort was adjusted on the basis of comorbidities

Low/intermediate comorbidities include: history of myocardial infarction, ulcer, acute myocardial infarction, rheumatologic disease, peripheral vascular disease, diabetes, paralysis and cerebrovascular disease

High comorbidities include chronic obstructive pulmonary disease; congestive heart failure, liver disease including cirrhosis and chronic hepatitis, chronic renal failure, dementia and AIDS. None indicates none of the above reported

decision on treatment. Further research should focus on the impact of comorbidities and frailty on YLLs, so they would be more specific for individual patients.

In conclusion, we found that for CRC patients over 80 years old, the diagnosis CRC costs them on average 2.2 years of their lives. In this cohort, Stage I–III patients that underwent surgery had a life expectancy similar to that of the matched general population and fared much better than those who did not. The novel approach to assess the impact of CRC diagnosis and subsequent treatment in YLLs offers a different perspective that could be helpful for shared decision making. However, limitations should be acknowledged supporting the need for including comorbidity data to produce a comprehensive assessment of YLLs.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Ait Ouakrim D, Pizot C, Boniol M et al (2015) Trends in colorectal cancer mortality in Europe: retrospective analysis of the WHO mortality database. BMJ 351:h4970
2. Ferlay J, Soerjomataram I, Dikshit R et al (2015) Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012. Int J Cancer 136(5):E359–E386
3. World Health Organization—life expectancy and healthy life expectancy. http://apps.who.int/gho/data/node.main.688. Accessed May 2018
4. Schurer W (2010) The status of colorectal cancer care in The Netherlands: past, present and future. Eur J Health Econ 10(Suppl 1):S51–S56
5. Colorectal Cancer Collaborative Group (2000) Surgery for colorectal cancer in elderly patients: a systematic review. Lancet 356:968–974
6. Morris EJ, Taylor EF, Thomas JD et al (2011) Thirty-day postoperative mortality after colorectal cancer surgery in England. Gut 60:806–813
7. Verweij NM, Schiphorst AH, Maas HA et al (2016) Colorectal cancer resections in the oldest old between 2011 and 2012 in The Netherlands. Ann Surg Oncol 23:1875–1882
8. van Leersum NJ, Janssen-Heijnen ML, Wouters MW et al (2013) Increasing prevalence of comorbidity in patients with colorectal cancer in the South of The Netherlands 1995–2010. Int J Cancer 132:2157–2163
9. Devon KM, Vergara-Fernandez O, Victor JC et al (2009) Colorectal cancer surgery in elderly patients: presentation, treatment, and outcomes. Dis Colon Rectum 52:1272–1277
10. Dekker JW, Gooiker GA, Bastiaannet E et al (2014) Cause of death the first year after curative colorectal cancer surgery; a prolonged impact of the surgery in elderly colorectal cancer patients. Eur J Surg Oncol 40:1481–1487
11. Brustugun OT, Møller B, Helland A (2014) Years of life lost as a measure of cancer burden on a national level. Br J Cancer 111:1014–1020
12. Le Teuff G, Abrahamowicz M, Bolard P et al (2005) Comparison of Cox's and relative survival models when estimating the effects of prognostic factors on disease-specific mortality: a simulation study under proportional excess hazards. Stat Med 24:3887–3909
13. Centers for Disease Control and Prevention. MMWR. 2008; 57(45): 1226–1228. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5745a3.htm. Accessed May 2018
14. World Health Organization—years of life lost. http://www.who.int/whosis/whostat2006YearsOfLifeLost.pdf. Accessed May 2018
15. Jobsen JJ, Aarts MJ, Siesling S et al (2012) Use of primaryradiotherapy for rectalcancer in the Netherlands between 1997 and

2008: a population-based study. Clin Oncol (R Coll Radiol) 24:e1–e8
16. The Union for International Cancer Control (UICC)—TNM Classification. https://www.uicc.org/resources/tnm. Accessed May 2018
17. World Health Organization—International Classification of Diseases for Oncology (ICD-O). http://codes.iarc.fr/. Accessed May 2018
18. Chu PC, Wang JD, Hwang JS et al (2008) Estimation of life expectancy and the expected years of life lost in patients with major cancers: extrapolation of survival curves under high-censored rates. Value Health 11:1102–1109
19. Hwang JS, Wang JD (1999) Monte Carlo estimation of extrapolation of quality-adjusted survival for follow-up studies. Stat Med 18:1627–1640
20. World Health Organization—life tables by country: Netherlands. http://apps.who.int/gho/data/view.main.61160?lang=en. Accessed May 2018
21. Cucchetti A, Sposito C, Pinna AD et al (2016) Effect of age on survival in patients undergoing resection of hepatocellular carcinoma. Br J Surg 103:e93–e99
22. Wang JD (2002) Basic principles and practical applications in epidemiological research. World Scientific, Singapore
23. Cho H, Klabunde CN, Yabroff KR et al (2013) Comorbidity-adjusted life expectancy: a new tool to inform recommendations for optimal screening strategies. Ann Int Med 159:667–676
24. Cohen J (1988) Statistical power analysis for the behavioral sciencies. Lawrence Erlbaum Associates, Hillsdale
25. Ruscio J (2008) A probability-based measure of effect size: robustness to base rates and other factors. Psychol Methods 13(1):19–30
26. Kraemer HC, Kupfer DJ (2006) Size of treatment effects and their importance to clinical research and practice. Biol Psychiatry 59:990–996
27. Dekker JW, van den Broek CB, Bastiaannet E et al (2011) Importance of the first postoperative year in the prognosis of elderly colorectal cancer patients. Ann Surg Oncol 18:1533–1539
28. Othus M, Barlogie B, Leblanc ML et al (2012) Cure models as a useful statistical tool for analyzing survival. Clin Cancer Res 18:3731–3736
29. Van Cutsem E, Cervantes A, Adam R et al (2016) ESMO consensus guidelines for the management of patients with metastatic colorectal cancer. Ann Oncol 27:1386–1422
30. van Rooijen KL, Shi Q, Goey KKH et al (2018) Prognostic value of primary tumour resection in synchronous metastatic colorectal cancer: individual patient data analysis of first-line randomised trials from the ARCAD database. Eur J Cancer 91:99–106
31. Karoui M, Roudot-Thoraval F, Mesli F et al (2011) Primary colectomy in patients with stage IV colon cancer and unresectable distant metastases improves overall survival: results of a multicentric study. Dis Colon Rectum 54:930–938
32. Muss HB, Biganzoli L, Sargent DJ et al (2007) Adjuvant therapy in the elderly: making the right decision. J Clin Oncol 25:1870–1875
33. Gatta G, Zigon G, Aareleid T et al (2010) Patterns of care for European colorectal cancer patients diagnosed 1996–1998: a EUROCARE high resolution study. Acta Oncol 49:776–783
34. van Steenbergen LN, Rutten HJ, Creemers GJ et al (2010) Large age and hospital-dependent variation in administration of adjuvant chemotherapy for Stage III colon cancer in Southern Netherlands. Ann Oncol 21:1273–1278
35. Chawla N, Butler EN, Lund J et al (2013) Patterns of colorectal cancer care in Europe, Australia, and New Zealand. J Natl Cancer Inst Monogr 46:36–61
36. Doat S, Thiébaut A, Samson S et al (2014) Elderly patients with colorectal cancer: treatment modalities and survival in France. National data from the ThInDiT cohort study. Eur J Cancer 50:1276–1283
37. Altman DG, Bland JM (1999) Statistics notes. Treatment allocation in controlled trials: Why randomise? BMJ 318:1209

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.