


Nationwide cohort study of the impact of education, income and social isolation on survival after acute colorectal cancer surgery

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Background: Acute colorectal cancer surgery has been associated with a high postoperative mortality. The primary aim of this study was to examine the association between socioeconomic position and the likelihood of undergoing acute *versus* elective colorectal cancer surgery. A secondary aim was to determine 1-year survival among patients treated with acute surgery.

Methods: All patients who had undergone a surgical procedure according to the Danish Colorectal Cancer Group (DCCG.dk) database, or who were registered with stent or diverting stoma in the National Patient Register from 2007 to 2015, were reviewed. Socioeconomic position was determined by highest attained educational level, income, urbanicity and cohabitation status, obtained from administrative registries. Co-variables included age, sex, year of surgery, Charlson Co-morbidity Index score, smoking status, alcohol consumption, BMI, stage and tumour localization. Logistic regression analysis was performed to determine the likelihood of acute colorectal cancer surgery, and Kaplan–Meier and Cox proportional hazards regression methods were used for analysis of 1-year overall survival.

Results: In total, 35 661 patients were included; 5310 (14.9 per cent) had acute surgery. Short and medium education in patients younger than 65 years (odds ratio (OR) 1.58, 95 per cent c.i. 1.32 to 1.91, and OR 1.34, 1.15 to 1.55 respectively), low income (OR 1.12, 1.01 to 1.24) and living alone (OR 1.35, 1.26 to 1.46) were associated with acute surgery. Overall, 40.7 per cent of patients died within 1 year of surgery. Short education (hazard ratio (HR) 1.18, 95 per cent c.i. 1.03 to 1.36), low income (HR 1.16, 1.01 to 1.34) and living alone (HR 1.25, 1.13 to 1.38) were associated with reduced 1-year survival after acute surgery.

Conclusion: Low socioeconomic position was associated with an increased likelihood of undergoing acute colorectal cancer surgery, and with reduced 1-year overall survival after acute surgery.

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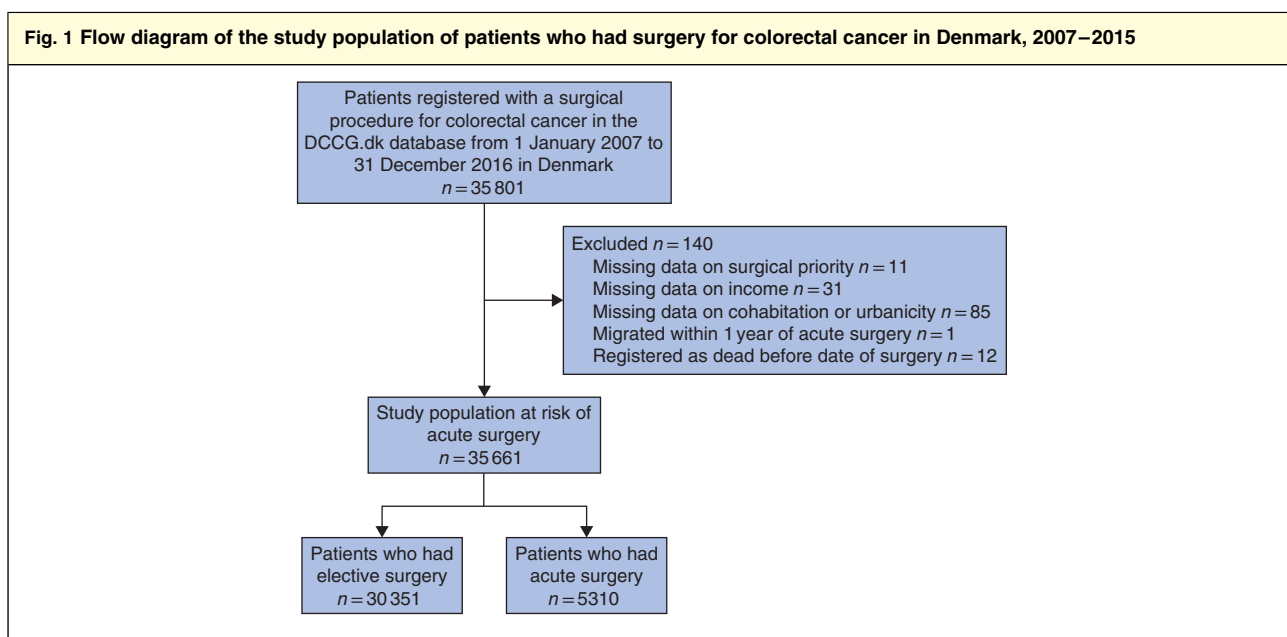
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Introduction

Low socioeconomic position is associated with poor short- and long-term survival after elective colorectal cancer surgery^{1–3}. These socioeconomic inequalities in survival are also observed where national healthcare service is available at no additional cost, such as in Scandinavian

countries^{1–3}. Socioeconomic position is an indicator of various social and economic factors that influence the position held in society on an individual and area/group level⁴. Socioeconomic factors can have an impact, both positive and negative, on various health-related exposures, and on economic resources that might be important for a healthy lifestyle⁴.



In addition, patients who present acutely with colorectal cancer, including obstruction, perforation of the bowel or bleeding, are at higher risk of poor outcome in the short and long term^{5,6}. It is crucial to identify risk factors for acute surgery in order to improve early detection of the disease and perioperative care, and initiate necessary rehabilitation.

The aim of this study was to investigate whether different aspects of socioeconomic position, such as the level of education, income, urbanicity and cohabitation, are associated with a greater likelihood of undergoing acute rather than elective colorectal cancer surgery. A secondary aim was to investigate whether these socioeconomic factors were associated with 1-year survival after acute colorectal cancer surgery.

Methods

Patients were included if they had undergone colorectal cancer surgery between 1 January 2007 and 31 December 2015, and were registered with a colorectal cancer diagnosis in the Danish Colorectal Cancer Group (DCCG.dk) database. The study protocol was registered on ClinicalTrials.gov in July 2018 (NCT number NCT03581890)⁷.

Patients were excluded if they had missing data on surgical priority (acute or elective), income up to 3 years before surgery or cohabitation the year before surgery, if they had migrated or disappeared within 1 year after acute surgery,

or were registered as an error with a surgical procedure dated after time of death.

The study was reported according to the STROBE⁸ and extended RECORD⁹ checklist criteria. It was reported to the Danish Data Protection Agency (registration number 2015-41-3726), but registration with the Danish Ethical Committee was not required according to Danish regulation.

Procedures were conducted in all 17 Danish hospitals that performed colorectal surgery in the study period. Of note, all primary care and hospital care expenses, including diagnostics, treatment and rehabilitation, are free of charge in Denmark, financed by a tax-based system, and no private facilities for treatment of colorectal cancer currently exist.

Data source

National registries, including the DCCG.dk database and other Danish registries, were the data sources. Data between registries are connected using the personal identification number (CPR) provided to all Danish citizens and people with a Danish residence permit^{10,11}.

The DCCG.dk database is a nationwide clinical database established in 2001, registering all incident cases of colorectal cancer in Denmark, with a greater than 95 per cent patient coverage¹². Patients are registered in the database when they are diagnosed and/or treated for colorectal cancer at any Danish surgical department¹². Data on patients undergoing a surgical procedure are collected prospectively by the surgical departments and documented

Table 1 Clinical features of 35 661 patients treated with surgery for colorectal cancer in Denmark, 2007–2015					
	Highest attained education				Total
	Short	Medium	Long	Missing	
No. of patients	10 751 (30.1)	16 804 (47.1)	6 720 (18.8)	1 386 (3.9)	35 661 (100)
Surgical mode					
Acute	1 791 (16.7)	2 302 (13.7)	847 (12.6)	370 (26.7)	5 310 (14.9)
Elective	8 960 (83.3)	14 502 (86.3)	5 873 (87.4)	1 016 (73.3)	30 351 (85.1)
Age (years)					
Median*					71 (50–87)
< 65	1 955 (18.2)	6 208 (36.9)	2 937 (43.7)	207 (14.9)	11 307 (31.7)
65–70	1 686 (15.7)	3 218 (19.2)	1 255 (18.7)	122 (8.8)	6 281 (17.6)
71–75	2 289 (21.3)	3 080 (18.3)	1 126 (16.8)	139 (10.0)	6 634 (18.6)
> 75	4 821 (44.8)	4 298 (25.6)	1 402 (20.9)	918 (66.2)	11 439 (32.1)
Sex					
M	4 981 (46.3)	9 622 (57.3)	3 890 (57.9)	629 (45.4)	19 122 (53.6)
F	5 770 (53.7)	7 182 (42.7)	2 830 (42.1)	757 (54.6)	16 539 (46.4)
CCI score					
0	5 984 (55.7)	10 379 (61.8)	4 502 (67.0)	671 (48.4)	21 536 (60.4)
1	2 138 (19.9)	2 848 (16.9)	1 006 (15.0)	338 (24.4)	6 330 (17.8)
2	1 247 (11.6)	1 797 (10.7)	591 (8.8)	174 (12.6)	3 809 (10.7)
≥ 3	1 382 (12.9)	1 780 (10.6)	621 (9.2)	203 (14.6)	3 986 (11.2)
BMI (kg/m²)					
< 18.5	379 (3.5)	446 (2.7)	172 (2.6)	78 (5.6)	1 075 (3.0)
18.5–25	3 841 (35.7)	6 517 (38.8)	3 052 (45.4)	551 (39.8)	13 961 (39.1)
> 25–30	3 171 (29.5)	5 350 (31.8)	2 048 (30.5)	291 (21.0)	10 860 (30.5)
> 30	1 677 (15.6)	2 535 (15.1)	718 (10.7)	116 (8.4)	5 046 (14.1)
Missing	1 683 (15.7)	1 956 (11.6)	730 (10.9)	350 (25.3)	4 719 (13.2)
Smoking status					
Never smoked	3 229 (30.0)	5 221 (31.1)	2 379 (35.4)	433 (31.2)	11 262 (31.6)
Former smoker	3 565 (33.2)	5 895 (35.1)	2 433 (36.2)	373 (26.9)	12 266 (34.4)
Smoker	1 854 (17.2)	3 038 (18.1)	895 (13.3)	177 (12.8)	5 964 (16.7)
Missing	2 103 (19.6)	2 650 (15.8)	1 013 (15.1)	403 (29.1)	6 169 (17.3)
Alcohol consumption (units/week)					
0	3 155 (29.3)	3 249 (19.3)	1 111 (16.5)	422 (30.4)	7 937 (22.3)
1–14	4 803 (44.7)	8 832 (52.6)	3 566 (53.1)	458 (33.0)	17 659 (49.5)
15–21	358 (3.3)	1 187 (7.1)	595 (8.9)	51 (3.7)	2 191 (6.1)
> 21	337 (3.1)	1 029 (6.1)	498 (7.4)	62 (4.5)	1 926 (5.4)
Missing	2 098 (19.5)	2 507 (14.9)	950 (14.1)	393 (28.4)	5 948 (16.7)
Income quintile					
1st	2 788 (25.9)	3 286 (19.6)	569 (8.5)	320 (23.1)	6 963 (19.5)
2nd	2 909 (27.1)	3 707 (22.1)	677 (10.1)	307 (22.2)	7 600 (21.3)
3rd	2 012 (18.7)	3 771 (22.4)	1 310 (19.5)	250 (18.0)	7 343 (20.6)
4th	1 177 (10.9)	3 354 (20.0)	2 325 (34.6)	271 (19.6)	7 127 (20.0)
5th	1 865 (17.3)	2 686 (16.0)	1 839 (27.4)	238 (17.2)	6 628 (18.6)
Urbanicity					
City	3 280 (30.5)	7 393 (44.0)	3 511 (52.2)	672 (48.5)	14 856 (41.7)
Town	3 983 (37.0)	4 919 (29.3)	1 674 (24.9)	365 (26.3)	10 941 (30.7)
Rural	1 866 (17.4)	2 889 (17.2)	1 007 (15.0)	186 (13.4)	5 948 (16.7)
Peripheral	1 622 (15.1)	1 603 (9.5)	528 (7.9)	163 (11.8)	3 916 (11.0)
Cohabitation					
Living with a partner	5 840 (54.3)	11 406 (67.9)	4 760 (70.8)	509 (36.7)	22 515 (63.1)
Living alone	4 911 (45.7)	5 398 (32.1)	1 960 (29.2)	877 (63.3)	13 146 (36.9)

Table 1 Continued					
	Highest attained education				Total
	Short	Medium	Long	Missing	
UICC stage					
I	1636 (15.2)	2919 (17.4)	1257 (18.7)	149 (10.8)	5961 (16.7)
II	3545 (33.0)	5247 (31.2)	1958 (29.1)	466 (33.6)	11 216 (31.5)
III	2791 (26.0)	4412 (26.3)	1819 (27.1)	353 (25.5)	9375 (26.3)
IV	1882 (17.5)	2790 (16.6)	1169 (17.4)	244 (17.6)	6085 (17.1)
Missing	897 (8.3)	1436 (8.5)	517 (7.7)	174 (12.6)	3024 (8.5)
Tumour localization					
Right colon	3171 (29.5)	4391 (26.1)	1683 (25.0)	423 (30.5)	9668 (27.1)
Transverse colon	645 (6.0)	872 (5.2)	311 (4.6)	126 (9.1)	1954 (5.5)
Left colon	3567 (33.2)	5876 (35.0)	2522 (37.5)	495 (35.7)	12 460 (34.9)
Rectum	3344 (31.1)	5626 (33.5)	2180 (32.4)	338 (24.4)	11 488 (32.2)
Missing	24 (0.2)	39 (0.2)	24 (0.4)	4 (0.3)	91 (0.3)
Year of surgery					
2007–2010	4350 (40.5)	5799 (34.5)	2257 (33.6)	805 (58.1)	13 211 (37.0)
2011–2013	3190 (29.7)	5027 (29.9)	1946 (29.0)	316 (22.8)	10 479 (29.4)
2014–2016	3211 (29.9)	5978 (35.6)	2517 (37.5)	265 (19.1)	11 971 (33.6)

Values in parentheses are percentages unless indicated otherwise; *values in parentheses are 5 to 95 per cent range. CCI, Charlson Co-morbidity Index.

through a web-based platform. In the perioperative period, patient- and surgery-related data are registered. Pathological disease characteristics, such as T and N category, are registered after surgery by a pathologist. Only patients with primary adenocarcinoma, mucinous adenocarcinoma, signet ring cell carcinoma, medullary carcinoma or undifferentiated carcinoma are included in the database; metachronous colorectal cancers are not registered¹².

The National Patient Register (NPR) is a nationwide register established in 1977, with data on all patient contacts to Danish hospitals¹³. It is considered among the most comprehensive of its kind¹³, and includes data on diagnosis according to the ICD-10 (1994 to the present), time and date of admission, and priority of the admission registered at the end of each hospital contact.

Data on socioeconomic factors were obtained from nationwide administrative registers updated annually by Statistics Denmark by linking the personal identification number to different institutions¹⁴. The Danish education registries include information on all educational programmes in the country, of which some data date back as far as 1910¹⁵. Data on education are collected by the Danish Ministry of Education, and are generated from educational institutions. The highest obtained level of education was retrieved from the Danish education registries¹⁵. Data on disposable income were collected from registries on personal labour market affiliation, which contain information on employment status for all people registered on the Danish labour market¹⁶. Address and family status were

obtained from the Danish Civil Registration System, established in 1968 with continuous information on all people living in Denmark with a CPR number¹⁰.

Vital status was registered in the Danish Civil Registration Register¹⁰, and information on 1-year survival was linked to the DCCG.dk database in January 2017. Accordingly, all patients had 1-year follow-up, unless they had migrated or disappeared.

Socioeconomic indicators

Four socioeconomic factors were selected to cover different aspects of the influence on health. These included a knowledge-related asset (education), the economic resources reflecting the affordability of healthy lifestyle (income), geographical aspects and structural support (urbanicity), and social support (cohabitation)⁴.

Level of education was obtained by 1 October in the year before surgery. If information on educational level was missing, the level obtained up to 3 years before surgery was included, thus assuming that few patients would change educational level, considering that colorectal cancer generally occurs at a relatively older age. Education was categorized into three standardized categories: short (7 or 9 years of mandatory primary school for persons born before and after 1 January 1958 respectively), medium (10–12 years of schooling, corresponding to upper secondary school and vocational education) and long (more than 12 years of education, higher education). This

Table 2 Clinical features of 5310 patients undergoing acute surgery for colorectal cancer in Denmark, 2007–2015

	Highest attained education				Total
	Short	Medium	Long	Missing	
No. of patients	1791 (33.7)	2302 (43.4)	847 (16.0)	370 (7.0)	5310 (100)
1-year mortality	807 (45.1)	828 (36.0)	300 (35.4)	225 (60.8)	2160 (40.7)
90-day mortality	486 (27.1)	446 (19.4)	165 (19.5)	156 (42.2)	1253 (23.6)
Age (years)					
Median*					73 (50–90)
< 65	312 (17.4)	798 (34.7)	321 (37.9)	36 (9.7)	1467 (27.6)
65–70	227 (12.7)	417 (18.1)	140 (16.5)	19 (5.1)	803 (15.1)
71–75	283 (15.8)	367 (15.9)	131 (15.5)	17 (4.6)	798 (15.0)
> 75	969 (54.1)	720 (31.3)	255 (30.1)	298 (80.5)	2242 (42.2)
Sex					
M	759 (42.4)	1210 (52.6)	480 (56.7)	146 (39.5)	2595 (48.9)
F	1032 (57.6)	1092 (47.4)	367 (43.3)	224 (60.5)	2715 (51.1)
CCI score					
0	846 (47.2)	1284 (55.8)	483 (57.0)	144 (38.9)	2757 (51.9)
1	353 (19.7)	394 (17.1)	125 (14.8)	91 (24.6)	963 (18.1)
2	229 (12.8)	229 (9.9)	81 (9.6)	51 (13.8)	590 (11.1)
≥ 3	363 (20.3)	395 (17.2)	158 (18.7)	84 (22.7)	1000 (18.8)
BMI (kg/m²)					
< 18.5	100 (5.6)	101 (4.4)	28 (3.3)	23 (6.2)	252 (4.7)
18.5–25	634 (35.4)	926 (40.2)	388 (45.8)	131 (35.4)	2079 (39.2)
> 25–30	367 (20.5)	514 (22.3)	197 (23.3)	53 (14.3)	1131 (21.3)
> 30	168 (9.4)	210 (9.1)	54 (6.4)	15 (4.1)	447 (8.4)
Missing	522 (29.1)	551 (23.9)	180 (21.3)	148 (40.0)	1401 (26.4)
Smoking status					
Never smoked	439 (24.5)	587 (25.5)	268 (31.6)	103 (27.8)	1397 (26.3)
Former smoker	409 (22.8)	554 (24.1)	217 (25.6)	56 (15.1)	1236 (23.3)
Smoker	311 (17.4)	486 (21.1)	118 (13.9)	36 (9.7)	951 (17.9)
Missing	632 (35.3)	675 (29.3)	244 (28.8)	175 (47.3)	1726 (32.5)
Alcohol consumption (units/week)					
0	489 (27.3)	484 (21.0)	176 (20.8)	101 (27.3)	1250 (23.5)
1–14	590 (32.9)	915 (39.7)	363 (42.9)	85 (23.0)	1953 (36.8)
15–21	38 (2.1)	119 (5.2)	36 (4.3)	6 (1.6)	199 (3.7)
> 21	46 (2.6)	121 (5.3)	48 (5.7)	8 (2.2)	223 (4.2)
Missing	628 (35.1)	663 (28.8)	224 (26.4)	170 (45.9)	1685 (31.7)
Income quintile					
1st	480 (26.8)	455 (19.8)	72 (8.5)	94 (25.4)	1101 (20.7)
2nd	481 (26.9)	554 (24.1)	88 (10.4)	93 (25.1)	1216 (22.9)
3rd	356 (19.9)	504 (21.9)	184 (21.7)	67 (18.1)	1111 (20.9)
4th	172 (9.6)	429 (18.6)	301 (35.5)	64 (17.3)	966 (18.2)
5th	302 (16.9)	360 (15.6)	202 (23.8)	52 (14.1)	916 (17.3)
Urbanicity					
City	589 (32.9)	1061 (46.1)	457 (54.0)	177 (47.8)	2284 (43.0)
Town	636 (35.5)	637 (27.7)	200 (23.6)	98 (26.5)	1571 (29.6)
Rural	315 (17.6)	379 (16.5)	123 (14.5)	49 (13.2)	866 (16.3)
Peripheral	251 (14.0)	225 (9.8)	67 (7.9)	46 (12.4)	589 (11.1)
Cohabitation					
Living with a partner	801 (44.7)	1376 (59.8)	524 (61.9)	98 (26.5)	2799 (52.7)
Living alone	990 (55.3)	926 (40.2)	323 (38.1)	272 (73.5)	2511 (47.3)

Table 2 Continued					
	Highest attained education				Total
	Short	Medium	Long	Missing	
UICC stage					
I	27 (1.5)	38 (1.7)	15 (1.8)	8 (2.2)	88 (1.7)
II	449 (25.1)	564 (24.5)	169 (20.0)	86 (23.2)	1268 (23.9)
III	438 (24.5)	552 (24.0)	193 (22.8)	82 (22.2)	1265 (23.8)
IV	714 (39.9)	997 (43.3)	412 (48.6)	119 (32.2)	2242 (42.2)
Missing	163 (9.1)	151 (6.6)	58 (6.8)	75 (20.3)	447 (8.4)
Tumour localization					
Right colon	572 (31.9)	684 (29.7)	267 (31.5)	108 (29.2)	1631 (30.7)
Transverse colon	161 (9.0)	197 (8.6)	65 (7.7)	49 (13.2)	472 (8.9)
Left colon	826 (46.1)	1124 (48.8)	413 (48.8)	175 (47.3)	2538 (47.8)
Rectum	215 (12.0)	260 (11.3)	81 (9.6)	34 (9.2)	590 (11.1)
Missing	17 (0.9)	37 (1.6)	21 (2.5)	4 (1.1)	79 (1.5)
Year of surgery					
2007–2010	782 (43.7)	881 (38.3)	312 (36.8)	225 (60.8)	2200 (41.4)
2011–2013	574 (32.0)	815 (35.4)	291 (34.4)	90 (24.3)	1770 (33.3)
2014–2016	435 (24.3)	606 (26.3)	244 (28.8)	55 (14.9)	1340 (25.2)

Values in parentheses are percentages unless indicated otherwise; *values in parentheses are 5 to 95 per cent range. CCI, Charlson Co-morbidity Index.

corresponds to the International Standard Classification of Education (ISCED 2011) codes; short (ISCED codes 1–2, 9 years or less), medium (ISCED 3–4, 10–12 years) and long (ISCED 5–8, more than 12 years)¹⁷. Disposable income level was obtained from the registries on personal labour market affiliation in the year before surgery. Patients with missing values on income in the year before surgery were registered with their income up to 3 years before surgery. Income was grouped into quintiles, taking the annual median age- and sex-adjusted income in Denmark into account. Urbanicity is a variable based on geographical resources in the area of the patient's home address, such as number of inhabitants and distance to a main road¹⁸. This variable reflects structural support from the healthcare system, and is categorized into city, town, rural or peripheral areas. Cohabitation status was defined as living with a partner (married or cohabiting) or living without a partner (single, widowed or divorced), and reflects emotional and instrumental support. Urbanicity and cohabitation status were obtained from the Danish Civil Registration System at the beginning of the year of surgery for each patient.

Co-variables

Data obtained from the DCCG.dk database included age, sex, year of surgery, co-morbidity (Charlson Co-morbidity Index score (0, 1, 2 and 3 or more), smoking status (never smoked, former smoker (more than 8 weeks) or current smoker), alcohol consumption per week (0, 1–14, 15–21

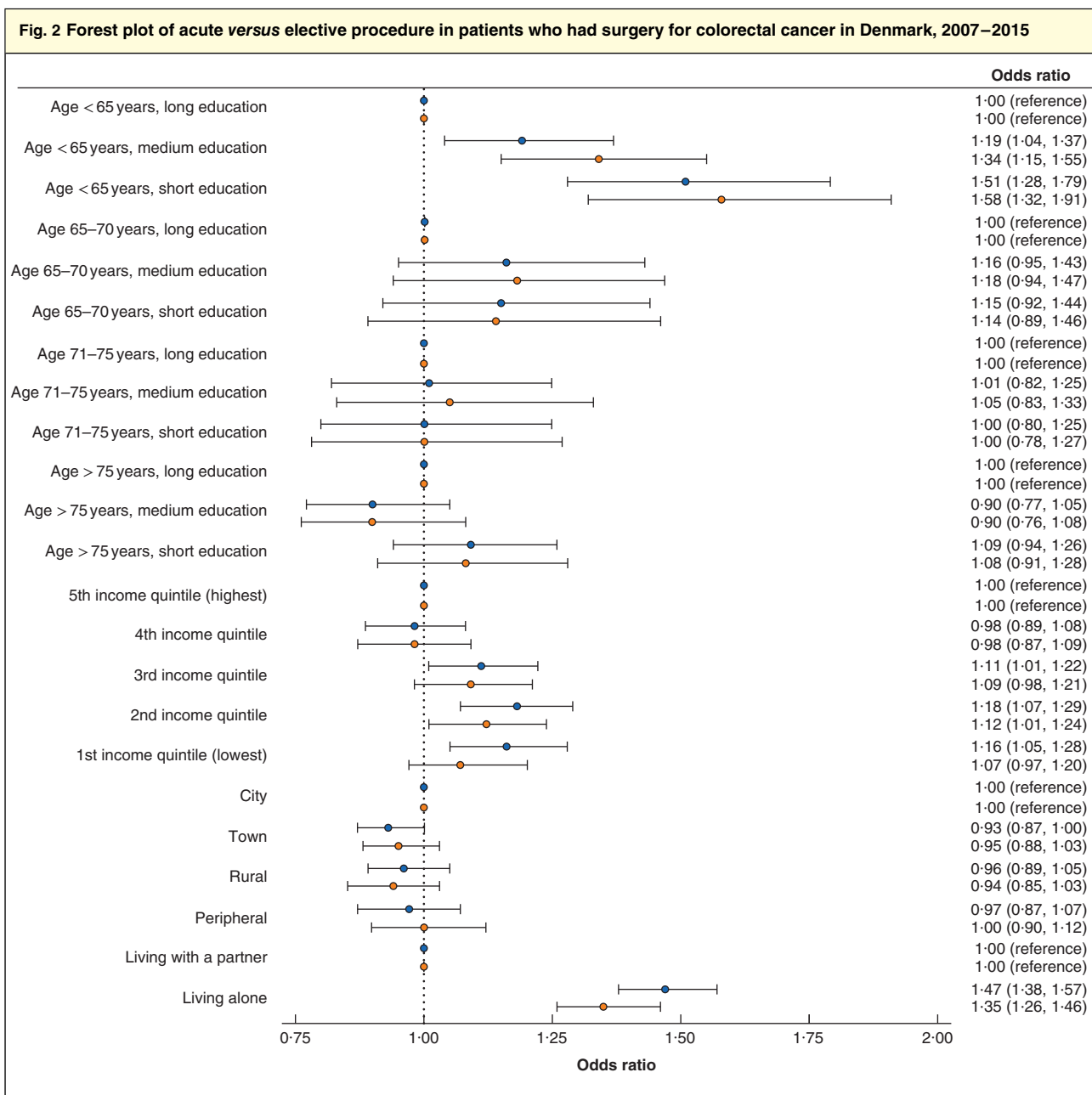
or over 21 units per week), BMI (less than 18.5, 18.5–25, more than 25–30 or more than 30 kg/m²), UICC stage (I–IV) and localization of the tumour (right colon, transverse colon, left colon or rectum, defined as less than 15 cm from the anal verge).

Outcome measures

The two primary outcomes were the likelihood of acute colorectal cancer surgery and 1-year survival analysis in patients who had an acute procedure. Acute surgery was defined as the patient being registered by the operating surgeon in the DCCG.dk database with an acute procedure, or registered in the NPR with a diverting stoma or insertion of a self-expanding metallic stent (SEMS) in the colon or rectum within 72 h of an acute admission to any department. ICD-10 codes were used to identify these procedures: diverting stoma (KJFF10, KJFF11, KJFF20, KJFF21, KJFF23, KJFF24, KJFF26, KJFF27, KJFF30 and KJFF31) and SEMS in the colon or rectum (KJFA68 and KJGA58A). Overall survival was defined as all-cause mortality calculated 1 year after surgery, and 90-day mortality was defined as all-cause mortality within 90 days of the surgical procedure. No patients were excluded or censored.

Statistical analysis

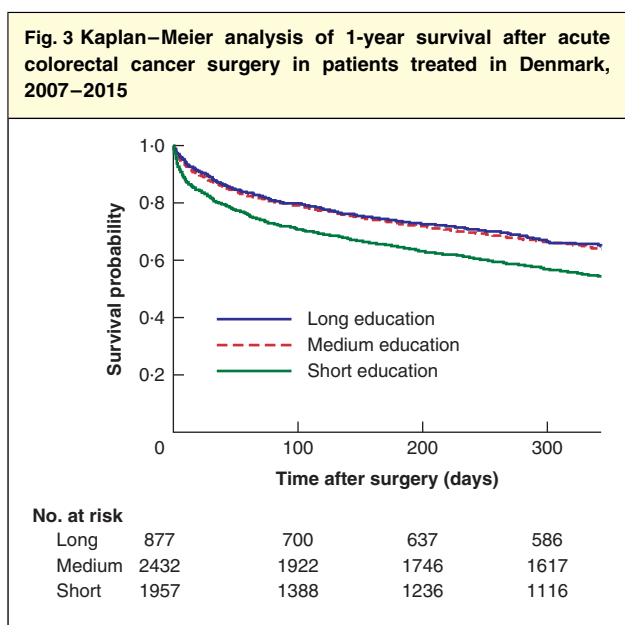
The association between socioeconomic position and acute *versus* elective colorectal cancer surgery was analysed using



Values in parentheses are 95 per cent confidence intervals. For each condition, the top (blue) odds ratio (OR) is adjusted for sex, age and year of surgery, and the lower (orange) OR is adjusted for sex, age, year of surgery, Charlson Co-morbidity Index score, BMI, smoking status, alcohol consumption, UICC stage and tumour localization. In addition, income quintile is adjusted for education, urbanicity is adjusted for education and income, and cohabitation is adjusted for education, income and urbanicity.

a logistic regression model. There were no missing data on acute *versus* elective surgery. Missing data on highest educational level, BMI, alcohol consumption, smoking status, tumour stage and localization were handled with multiple imputation using the fully conditional specification method. Ten imputed data sets were generated

with all variables included in the multiple imputation, including the primary outcome, acute surgery. The model was adjusted for confounders (age, sex and year of surgery), and in a second model for potential mediators (CCI score, BMI, smoking status, alcohol consumption, tumour localization and UICC stage). Age was the only continuous



variable. Linearity was tested by inserting a squared term in the model, finding age to be non-linear. Thus, in the model, age was included as a linear spline with cut points at the tertiles. Interactions between education, co-morbidity and age were tested.

Among patients who had acute surgery, the association between socioeconomic position and 1-year survival was investigated with Cox proportional hazards regression models, with time from surgery as the underlying timescale. There were no missing data on 1-year survival. Missing data on highest attained level of education, BMI, alcohol consumption, smoking status, tumour stage and localization were handled with multiple imputation using the fully conditional specification method. Ten imputed data sets were generated with all variables included in the multiple imputation, including the primary outcome, 1-year survival. The model was adjusted for confounders (age, sex and year of surgery), and in a second model for potential mediators (CCI score, BMI, smoking status, alcohol consumption, tumour localization and UICC stage). All variables in the model and 1-year survival were included in the imputation.

Survival analysis according to education was conducted using Kaplan–Meier curves after multiple imputation. A Cox proportional hazards regression model was also used to determine whether there was a difference in 90-day mortality in patients who had acute surgery, adjusted for age, sex, year of surgery, CCI score, BMI, smoking status, alcohol consumption, tumour localization and UICC stage.

All results were presented with the corresponding 95 per cent confidence intervals. Analyses were performed using SAS® version 9.3 software (SAS Institute, Cary, North Carolina, USA).

Results

Between 2007 and 2015, 35 801 patients were eligible for inclusion. Some 140 patients were excluded according to study criteria, only one patient owing to migration within 1 year after acute surgery. On this basis, 35 661 patients were included, 30 351 (85.1 per cent) underwent elective surgery and 5310 (14.9 per cent) had acute surgery (Fig. 1).

The majority of patients (73.3 per cent) who had acute surgical treatment were extracted from the DCCG.dk database, and the remainder (26.7 per cent) were from the NPR.

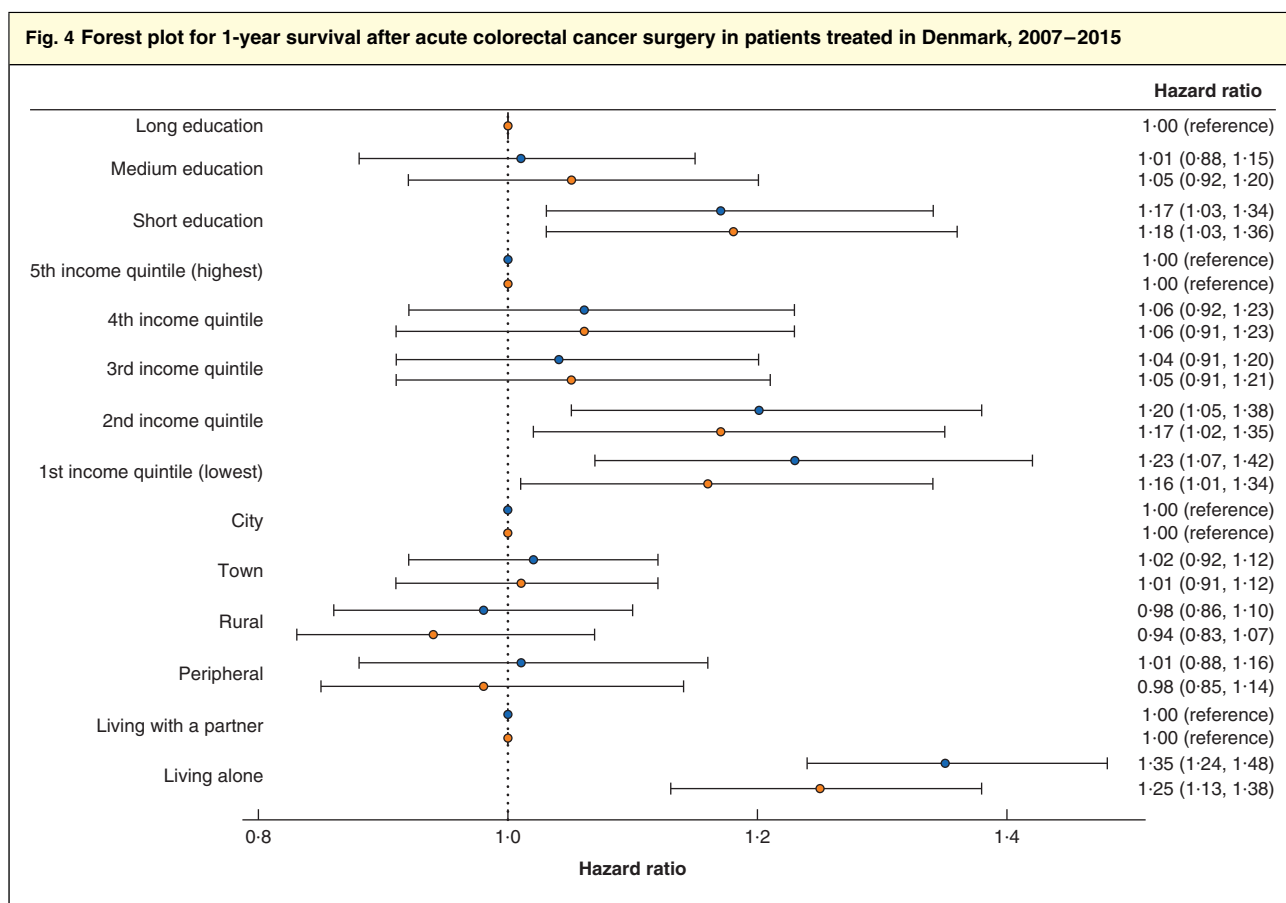
Educational level was missing for 3.9 per cent of patients, the majority of whom (66.2 per cent) were more than 75 years old. The variables smoking status and alcohol consumption had the highest proportion of missing data, with 17.3 and 16.7 per cent missing respectively (Table 1). Among patients who had acute surgery, information on BMI, smoking status and alcohol consumption was missing in 26.4, 32.5 and 31.7 per cent respectively (Table 2).

Risk of acute versus elective surgery

Some 16.7 per cent of patients with a short education had acute surgical treatment, compared with 12.6 per cent of patients with a long education (Table 1). A greater proportion of patients with a short education reported a smoking habit (17.2 per cent), had co-morbidities (44.3 per cent) and a BMI above 30 kg/m² (15.6 per cent). However, an extensive alcohol intake of more than 21 units per week was more common among patients with a prolonged education. UICC stage III and IV were equally distributed according to education in all patients (Table 1); however, among patients who had acute surgery, there was a higher proportion of stage IV in patients with a long education (48.6 per cent) (Table 2).

In the logistic regression model, short and medium educational levels were associated with an increased risk of having colorectal cancer requiring acute surgery in patients younger than 65 years compared with patients with a longer education, when adjusting for age, sex, year of surgery, co-morbidity, BMI, smoking status, alcohol consumption, UICC stage and tumour localization (odds ratio (OR) 1.58, 95 per cent c.i. 1.32 to 1.91, and OR 1.34, 1.15 to 1.55, respectively) (Fig. 2).

No association between education and the likelihood of acute surgery was observed for other age groups. Low



Values in parentheses are 95 per cent confidence intervals. For each condition, the top (blue) hazard ratio (HR) is adjusted for sex, age and year of surgery, and the lower (orange) HR is adjusted for sex, age, year of surgery, Charlson Co-morbidity Index score, BMI, smoking status, alcohol consumption, UICC stage and tumour localization. In addition, income quintile is adjusted for education, urbanicity is adjusted for education and income, and cohabitation is adjusted for education, income and urbanicity.

income was associated with an increased risk of acute surgery, significant only in the second lowest income quintile group (OR 1.12, 95 per cent c.i. 1.01 to 1.24) when adjusting for the same co-variables and for education. There was no association between urbanicity and acute surgery in the adjusted model. Living alone was associated with an increased risk of acute surgery (OR 1.35, 1.26 to 1.46) in the fully adjusted model (Fig. 2). The association between confounders/mediators and the risk of acute colorectal cancer surgery is shown in Fig. S1 (supporting information).

Ninety-day mortality

In acutely operated patients, short education was associated with 90-day mortality in the fully adjusted model, although it failed to reach statistical significance (adjusted hazard ratio (HR) 1.14, 95 per cent c.i. 0.99 to 1.32).

One-year overall survival after acute colorectal cancer surgery

Some 40.7 per cent of patients died within the first year after acute surgery. Kaplan–Meier analysis showed that unadjusted 1-year survival after acute surgery was lower in patients with a short education (Fig. 3). The survival difference between patients having a short education *versus* those with a medium or long education increased gradually over time.

Shorter educational level was associated with poor 1-year survival after acute colorectal cancer surgery when adjusted for age, sex, year of surgery, co-morbidity, BMI, smoking status, alcohol consumption, UICC stage and tumour localization (HR 1.18, 95 per cent c.i. 1.03 to 1.36) (Fig. 4). In addition, low income was associated with reduced 1-year survival after adjustment: HR 1.16 (1.01 to 1.34) in the lowest income quintile and 1.17 (1.02 to 1.35) in the second lowest income quintile. Urbanicity

did not have any association with 1-year survival after full adjustment. Living alone was associated with poor survival (adjusted HR 1.25, 1.13 to 1.38) (Fig. 4). The association between confounders/mediators and 1-year survival after acute colorectal cancer surgery is shown in Fig. S2 (supporting information).

Discussion

Despite many structural changes in the treatment of colorectal cancer in the past 10 years and a healthcare system free of charge^{19,20}, there are still differences in the risk of acute surgery and 1-year survival after acute surgery according to socioeconomic status in Denmark. Ten years ago, a Danish nationwide study¹ showed that longer education and living in an owned house improved 30-day survival after elective colorectal cancer surgery compared with that of patients living in a rented house.

Identifying patients by means of screening programmes could reduce the proportion of acutely operated patients. A British study²¹ recently documented a 40 per cent reduction in acutely operated patients after the introduction of colorectal cancer screening. Participation in a colorectal cancer screening programme also shows a socioeconomic gradient. Three recent studies^{22–24} found that participation in screening increases with level of education and income, and in patients living with a partner. Low socioeconomic status was also associated with the likelihood of submitting a stool sample ineligible for analysis²⁵. A recent French randomized trial²⁶ with 16 250 participants aimed to improve participation in colorectal screening by introducing a navigator programme. A specially trained social worker contacted non-participant individuals by phone, mail or home visits. The overall participation rate improved significantly, from 21 to 24 per cent, with a higher increase in individuals living in affluent areas²⁶. Taken together, the present results and previous findings indicate that different approaches to the screening and treatment of patients with low socioeconomic status might need to be considered in future studies.

In this study, patients who had acute colorectal cancer surgery with short education, low income and lone living were found to have poor 1-year survival. In all age groups, low income and living alone were associated with acute surgery, but in patients aged less than 65 years education was a risk factor for acute surgery. In addition, the risk estimate for short education on survival after acute surgery did not change when adjusting for UICC stage, co-morbidity and lifestyle factors. Thus, these potential mediating factors did not seem to explain the social gradient in survival. A Dutch study²⁷ of 6736 patients with colorectal

cancer found that age, co-morbidity and acute surgery explained the socioeconomic differences in postoperative 30-day mortality following colonic, but not rectal, cancer procedures. Another large study²⁸ including more than 7000 patients with colorectal cancer also showed that differences in postoperative 30-day mortality correlated with emergency surgery. However, in the full model adjusting for stage of disease and co-morbidity, socioeconomic status was no longer associated with postoperative mortality.

A previous Danish nationwide study² conducted between 2001 and 2004, and including 8763 patients with colorectal cancer undergoing resection (85 per cent treated with elective procedures), showed improved long-term overall survival in patients with a high educational level in adjusted analysis. However, in contrast to the present study, the association between educational level and survival was mediated by lifestyle and, particularly, by co-morbidity². The social gradient did not appear to be mediated by lifestyle, co-morbidity or disease characteristics in the present population, and further investigation is warranted to improve treatment possibilities and survival in patients with colorectal cancer and low socioeconomic status.

The estimated effect of socioeconomic status may be stronger in countries where access to timely and optimal healthcare is a barrier for patients with low socioeconomic status²⁹. Research from 2014 in the USA showed an increased risk of emergency diagnosis of colorectal cancer in African Americans living in poor neighbourhoods³⁰.

A limitation of the present study could be the missing data on the main exposure, education (3.9 per cent of the study population), especially among older patients. Missing data for lifestyle factors, BMI, smoking status and alcohol consumption were also pronounced in patients undergoing acute surgery. Missing data were handled with multiple imputation³¹ and, in the process of imputation, all variables and the primary outcome were included.

A major strength of the study is that all analyses were based on a clinical database of Danish patients with colorectal cancer with 95–99 per cent completeness. Furthermore, all data in the study were collected prospectively into the registries, independently of the study hypothesis, minimizing the risk of recall bias. However, it should be noted that, among patients who had acute surgery, registries lack information on possible mediators such as the presence of sepsis or tumour perforation at the time of surgery, which could affect postoperative survival^{32,33}. Lack of these data could introduce residual mediation in the results and potentially lead to overestimating the effect of socioeconomic status on presentation and 1-year survival.

An increased focus on perioperative optimization, rehabilitation and surveillance within at least 1 year after acute

surgery could be beneficial in this high-risk patient group in improving survival.

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Disclosure

The authors declare no conflict of interest.

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Supporting information

Additional supporting information can be found online in the Supporting Information section at the end of the article.