



Short-term outcome of emergency colorectal cancer surgery: results from Bi-National Colorectal Cancer Audit

Chun Hin Angus Lee^{1,2} · Joseph Cherng Huei Kong² · Alexander G. Heriot^{1,2} · Satish Warriar^{1,2} · John Zalberg³ · Paul Sitzler¹

Accepted: 19 September 2018 / Published online: 30 September 2018
© Springer-Verlag GmbH Germany, part of Springer Nature 2018, corrected publication 2018

Abstract

Backgrounds A significant number of patients with colorectal cancer will have an emergency presentation requiring surgery. This study aims to evaluate short-term outcomes for patients undergoing emergency colorectal cancer surgery in Australasia.

Methods All consecutive CRC from the Bi-National Colorectal Cancer Audit Database was interrogated from 2007 to 2016. Short-term outcomes including length of stay, complication rate and mortality rate were compared between the emergency and elective groups. Logistic regression analysis was performed to identify independent predictors for inpatient mortality. A predictive model for inpatient mortality was constructed using these variables, and its accuracy was then validated by the Bootstrap re-sampling method.

Results Of 15,676 colorectal cancer cases identified, 13.6% were emergency cases. The emergency group had a higher rate of surgical and medical complications (26.7% vs 22.6%, $p < 0.001$; 22.8 vs 13.8%, $p < 0.001$, respectively). Higher inpatient mortality rate was also observed in the emergency group (3.4% vs 2.6%, $p = 0.023$). Independent predictors for inpatient survival included age, American Society Anaesthesiologists score, emergency surgery and tumour stage. In addition, postoperative complications such as anastomotic leak (odds ratio [OR] 3.78, $p < 0.001$), sepsis (OR 2.85, $p < 0.001$) and medical complications (OR 13.88, $p < 0.001$) had a significant impact in survival in the emergency group. Receiver operating characteristics curve for inpatient mortality was 0.913.

Conclusion Emergency colorectal cancer surgery carries significant morbidity and mortality. Recognition of the increasing rate of postoperative complications may help minimise the detrimental impact of this event on overall outcomes.

Keywords Emergency colorectal surgery · Colorectal cancer · Postoperative outcome

Introduction

Australia and New Zealand have the highest incidence of colorectal cancer in the world [1]. Although most patients are

diagnosed and treated in an elective setting, a significant number of patients (up to 22%) will have an emergency event requiring surgery as first presentation [2, 3]. Postoperative mortality in emergency colorectal cancer resection has been reported to be up to 20% despite perioperative care advancement in recent years [4, 5].

Current literature regarding the outcome of emergency colorectal cancer resection is limited to single institutional studies with small sample size. Furthermore, despite a strong initiative to deliver equal healthcare in Australia and New Zealand, survival disparity exists amongst a heterogeneous cohort with variable patient and tumour characteristics [6]. The primary objective of this retrospective study was to determine factors predicting short-term surgical outcomes in patients first presenting with colorectal cancer requiring emergency surgery, using a large population-based database.

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s00384-018-3169-5>) contains supplementary material, which is available to authorized users.

✉ Chun Hin Angus Lee
angus.lee@petermac.org

¹ Epworth Healthcare, Melbourne, VIC 3121, Australia

² Division of Cancer Surgery, Peter MacCallum Cancer Centre, Melbourne, VIC 3000, Australia

³ Cancer Research Program, School of Public Health & Preventive Medicine, Faculty of Medicine, Monash University, Monash, Melbourne, VIC 3004, Australia

Methods

The Bi-National Colorectal Cancer Audit (BCCA) is a prospectively maintained database of primary colorectal cancer patients undergoing surgery in Australia and New Zealand. Data entry is entirely voluntary and performed by treating surgeons who are registered users (both general surgeons and colorectal rectal surgeons; $n = 369$) for the BCCA database. It captures approximately 2500 cases of new colorectal cancer each year which represents 15% of all newly diagnosed cancer in both nations [7]. Ethics approval was obtained from Epworth Hospital (EH 2017-196), and permission was granted by the BCCA Research Committee to obtain data from the database. De-identified data containing patient's demographics, tumour pathology, surgical treatment and outcome of consecutive adult patients who underwent colorectal cancer surgery from January 2007 to December 2016 were extracted.

The inclusion criteria were adult patients with a confirmed diagnosis of colorectal cancer. All duplicates or had subsequent operation(s) were excluded from this analysis. Urgency of the operations were classified as emergency, urgent and elective. Emergency operations were defined as life-saving operations performed usually within an hour upon admission, whereas urgent operations were defined as surgeries performed as soon as possible after resuscitation and usually within 24 h. Operations were considered as elective if they were scheduled in advance. Data from emergency and urgent operations were combined into emergency group during data analysis, and comparison was made between emergency and elective groups.

Postoperative outcome measures of interest included the rate of medical and surgical complications, anastomotic leak rate, hospital length of stay (LOS) and inpatient mortality. Surgical complications included the following: (1) abdominal pelvic collection, (2) anastomotic leak, (3) wound infection, (4) superficial wound dehiscence, (5) deep wound dehiscence, (6) entero-cutaneous fistula, (7) sepsis, (8) prolonged ileus, (9) mechanical small bowel obstruction, (10) urinary retention requiring catheterisation, (11) intraoperative ureteric injury, (12) splenectomy and (13) postoperative haemorrhage requiring transfusion or operative management. Medical complications included the following: (1) cardiac, (2) chest infection, and (3) deep vein thrombosis and pulmonary embolism. Detailed descriptions of each complications were outlined in [supplementary material](#).

An assessment of socioeconomic status (SES) was performed by identifying each patient's postcode matched with various income data from the Australian (2016) and New Zealand (2013) Government Census database. A low SES status was defined as mean annual income, education level and unemployment rate below

the 20th percentile. Hospitals were classified into urban and rural hospitals based on population size of the city where the hospitals were located. Urban hospitals were defined by a population size greater than 200,000 residents, whereas rural hospitals were defined as those in town population size less than 200,000.

Categorical variables were analysed using the Pearson chi-square test or Fisher's exact test. To create a predictive model for inpatient mortality, a univariate analysis was performed on all patients to identify significant predictors for inpatient mortality followed by stepwise multivariate logistic regression analysis to identify independent predictors.

For further validation of a new model, another new model coefficient incorporating variables from the initial model creation was performed through a split sample temporal validation, in which the sample was divided equally based on the time of admission. Any missing value in the validation set was replaced with a normal value or the least clinical severity score.

Receiver operating characteristics (ROC) curve was used to measure the ability of the predictive model to assign a higher probability of death to the patients that died compared to those that survived. A good predictive model has area under the curve (AUC) of 0.7–0.9, whereas AUC of more than 0.9 denotes an excellent model. Hosmer-Lemeshow goodness of fit test was used to measure the accuracy of the predictive model in determining outcome in individual patients.

All statistical analysis was performed using IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0 (Armonk, NY: IBM Corp.) and p value of < 0.05 is deemed to be statistically significant.

Results

Patients' demographics and tumour characteristics

A total of 16,847 cases of colorectal cancer were identified in the database. After exclusion of duplicates, there were a total of 15,676 consecutive colorectal cancer patients. Data entries were contributed by 284 surgeons across 102 hospitals. Table 1 outlines the patient's characteristics, tumour pathology and treatment received in the emergency and elective surgery groups. Overall, emergency surgery represented 13.6% ($n = 2129$) of all cases. Compared to the elective group, a higher proportion of patients in the emergency group were older, female, not privately insured and had a higher number of co-morbidities. Right-sided and more advanced stage cancers were also more common in the emergency group (56.6% had node-positive disease and

Table 1 Patient and tumour characteristics in emergency and elective groups

Variables	Emergency group, n (%)	Elective group, n (%)	p value
Age			
< 70	936 (44)	6547 (48.3)	
≥ 70	1193 (56)	7000 (51.7)	< 0.001
Sex			
Male	1061 (49.8)	7434 (54.9)	
Female	1068 (50.2)	6113 (45.1)	< 0.001
Total missing			8
ASA Score			
1	209 (10.2)	2059 (15.7)	
2	800 (38.9)	6359 (48.4)	
3	837 (40.7)	4314 (32.8)	
4	199 (9.7)	414 (3.1)	
5	13 (0.6)	4 (0)	< 0.001
Total missing	397	11	
Insurance status			
Public	1326 (62.8)	6682 (50.1)	
Private	785 (37.2)	6659 (49.9)	< 0.001
Total missing	18	206	
Treatment location			
Urban	11,757 (86.8)	1870 (88)	
Rural	1785 (13.2)	256(12)	0.156
Total missing			8
Low socioeconomic status			
No	1958 (97.5)	12,353 (97.7)	
Yes	51 (2.5)	292 (2.3)	0.529
Total missing	120	902	1022
Tumour site			
Caecum to transverse colon	1003 (47.6)	5016 (37.2)	
Splenic flexure to sigmoid colon	749 (35.6)	3102 (23)	
Upper rectum (> 12 cm)	194 (9.2)	1546 (11.5)	
Mid rectum (8–12 cm)	77 (3.7)	1575 (11.7)	
Lower rectum (< 8 cm)	82 (3.9)	2247 (16.7)	< 0.001
Total missing	24	61	
T stage			
0	7 (0.4)	535 (4.1)	
1	55 (2.8)	1848 (14.2)	
2	90 (4.6)	2345 (18)	
3	908 (46.1)	6415 (49.1)	
4	909 (46.2)	1915 (14.7)	< 0.001
Total missing	160	489	
N stage			
0	857 (43.4)	8481 (64.4)	
1	607 (30.7)	3085 (23.4)	
2	511 (25.9)	1613 (12.2)	< 0.001
Total missing	154	368	

Table 1 (continued)

Variables	Emergency group, n (%)	Elective group, n (%)	p value
M Stage			
0	1562 (73.4)	12,309 (90.9)	
1	567 (26.6)	1238 (9.1)	< 0.001
Margin status			
Negative	1109(89.2)	6776 (85.0)	< 0.001
Positive	135 (10.9)	1196 (15.0)	
Missing	885	5575	
Surgical entry			
Laparoscopic	402 (18.9)	5792 (42.8)	
Open	1582 (74.3)	6032 (44.5)	
Hybrid	38 (1.8)	593 (4.4)	
Lap converted to open	76 (3.6)	700 (5.2)	
Transanal	5 (0.2)	144 (1.1)	
Robotic	0	124 (0.9)	
taTME	0	35 (0.3)	
Surgical technique			
Right hemicolectomy	918 (43.2)	4570 (33.8)	
Left hemicolectomy	78 (3.7)	494 (3.7)	
Transverse colectomy	18 (0.8)	105 (0.8)	
Sigmoid colectomy	23 (1.1)	109 (0.8)	
Subtotal colectomy	145 (6.8)	331 (2.4)	
Total colectomy	61 (2.9)	129 (1.0)	
Hartmann’s procedure	271 (12.8)	320 (2.4)	
High anterior resection	303 (14.3)	2626 (19.4)	
Low anterior resection	83 (3.9)	1261 (9.3)	
Ultralow anterior resection	37 (1.7)	2046 (15.1)	
Proctocolectomy	7 (0.3)	127 (0.9)	
APR	18 (0.8)	927 (6.9)	
Others	163 (7.7)	477 (3.5)	
Missing	4	25	< 0.001
Lymph node harvested	19.4 (11.7)	17.1 (9.8)	< 0.001
Mean (SD)			

26.6% with metastatic disease compared to 35.6% and 9.1% in the elective group).

Treatment

74.3% of all emergency surgeries were performed with an open approach. Laparoscopic approach was feasible in 18.9% of the emergency group compared to 42.8% in the elective group with a conversion to open rate of 15.9% compared to 10.5% in the elective group. When comparing to the elective group, emergency group had a higher rate of end stoma formation (end colostomy 15.3 vs 9.0; end ileostomy 6.7 vs 1.6; both *p* values < 0.001).

Short-term outcomes

Emergency surgery was associated with significant postoperative morbidities (Table 2). Both surgical and medical complication rates were significantly higher in the emergency surgery group (26.7 vs 22.6%, $p < 0.001$; 22.8 vs 13.8%, $p < 0.001$, respectively). Overall, anastomotic leak rate for the entire study cohort was 2.8% ($n = 421$). Primary anastomosis performed in the emergency setting had a significantly higher leak rate (3.4 vs 2.6%, $p = 0.023$).

Nonetheless, the overall unplanned return to theatre rate was similar.

Inpatient mortality was higher in the emergency surgery group (3.4 vs 1.1%, $p < 0.001$). Of note, a higher proportion of patients who died as an inpatient have experienced medical

or surgical complications in the emergency group compared to the elective group (78.7 vs 14.1 and 45.7% vs 22.8, respectively; both p values < 0.001). In a univariate model, factors such as age ≥ 70 , not privately insured, higher American Society of Anaesthesiologists score (ASA), proximal colon cancer, advanced stage cancer, emergency surgery and the presence of postoperative complication (surgical and medical) were associated with inpatient mortality. After adjusting all clinical significant co-variables, only age ≥ 70 , higher ASA score, higher T stage, emergency surgery and the presence of postoperative complication were independent risk factors associated with inpatient mortality (Table 3).

Emergency surgery was also associated with prolonged hospital LOS compared to elective surgery (mean number of days 18 vs 12, $p = 0.036$).

Table 2 Postoperative outcomes in emergency and elective groups

Variables	Emergency group, n (%)	Elective group, n (%)	p value
Surgical complications			
No	1556 (73.3)	10,479 (77.4)	
Yes	566 (26.7)	3056 (22.6)	< 0.001
Total missing	19	0	
Anastomotic leak			
No	2056 (96.6)	13,199 (97.4)	
Yes	73 (3.4)	348 (2.6)	0.023
Superficial wound dehiscence			
No	2067 (97.1)	13,306 (98.2)	
Yes	62 (2.9)	241 (1.8)	0.001
Deep wound dehiscence			
No	2112 (99.2)	13,453 (99.3)	
Yes	17 (0.8)	94 (0.7)	0.588
Sepsis			
No	2053 (96.4)	13,279 (98)	
Yes	76 (3.6)	268 (2)	< 0.001
Prolonged ileus			
No	1866 (87.6)	12,383 (91.4)	
Yes	263 (12.4)	1164 (8.6)	< 0.001
Pelvic collection			
No	2062 (96.9)	13,198 (97.4)	
Yes	67 (3.1)	349 (2.6)	0.126
Medical complications			
No	1638 (77.2)	11,672 (86.2)	
Yes	484 (22.8)	1861 (13.8)	< 0.001
Returned to OT			
No	1986 (93.3)	12,766 (94.2)	
Yes	143 (6.7)	781 (5.8)	0.082
Inpatient mortality			
No	2056 (96.6)	13,399 (98.9)	
Yes	73 (3.4)	148 (1.1)	< 0.001
Mean LOS (SD)	18 (105.7)	12 (56.8)	0.036

Table 3 Multivariate analysis of factors correlating with inpatient mortality

Factors	Risk (%)	OR (95% CI)	<i>p</i> value
Urgent surgery	6.06	1.40 1.029–2.073	0.004
Age ≥ 70	9.55	2.30 1.521–3.467	< 0.001
ASA score			
1	Reference	– –	–
2	0.07	0.02 0.003–0.093	< 0.001
3	0.13	0.03 0.007–0.121	< 0.001
4	0.30	0.07 0.016–0.263	< 0.001
5	0.90	0.20 0.048–0.808	0.024
T stage			
0	Reference	– –	–
1	1.81	0.40 0.094–1.700	0.215
2	1.61	0.36 0.164–0.773	0.009
3	2.83	0.63 0.377–1.066	0.086
4	3.49	0.79 0.559–1.105	0.166
Anastomotic leak	14.82	3.78 2.307–6.202	< 0.001
Sepsis	11.58	2.85 1.802–4.495	< 0.001
Medical complications (cardiac/pulmonary/DVT and PE)	39.00	13.88 9.639–19.998	< 0.001

CI confidence interval, *DVT* deep vein thrombosis, *OR* odds ratio, *PE* pulmonary embolism

Predictive model for inpatient mortality

The initial predictive model for inpatient mortality was constructed incorporating all patients. Any preoperative variables with *p* value of less than 0.05 were introduced into the stepwise multivariate logistic regression analysis. These include age, ASA, urgency of operation, T stage and site. A ROC curve was performed which demonstrated AUC of 0.818 (standard error (SE) 0.0136, 95% confidence interval (CI) 0.812–0.824). This model was further improved when postoperative complications (anastomotic leak (OR 3.8, *p* < 0.001), sepsis (OR 2.8, *p* < 0.001) and medical complications (OR 13.9, *p* < 0.001)) were incorporated into the model generating a ROC curve of 0.913 (SE 0.0099, 95% CI 0.909–0.918) (Fig. 1).

Split sample temporal validation

A temporal validation was performed, splitting the database equally; however, 869 (11.1%) of 7839 were excluded due to missing data. A new model coefficient model was derived (supplementary material). This model had a AU ROC of 0.923 (95% CI 0.916 to 0.929, *p* value < 0.001). Subsequently, it was validated using the next 7838 cases, deriving a AUROC of 0.889 (95% CI 0.882 to 0.897, *p* value < 0.001).

Discussion

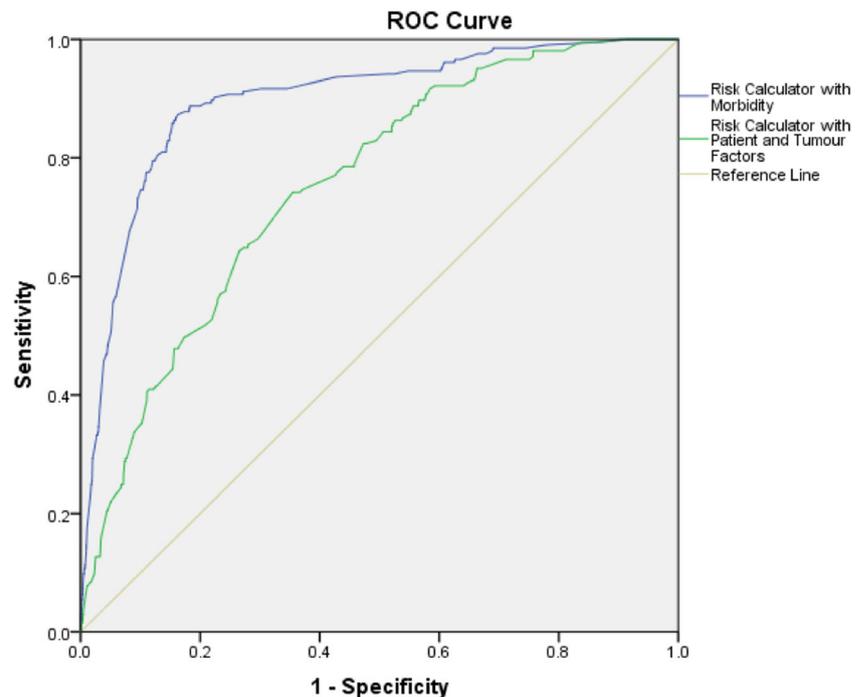
This study represents one of the largest series of colorectal cancer cases in Australasia, evaluating short-term outcomes in the emergency setting. Our study highlights that patients undergoing emergency colorectal cancer surgery were at high risk of developing postoperative complications which can be detrimental to short-term survival.

Colorectal cancer patients with emergency presentation tend to be older and have more advanced disease [8]. Intuitively, postoperative morbidity and mortality rate are higher in this group of patients. Worldwide, the mortality rate for emergency colorectal cancer surgery based on large population contemporary series from Europe, the United Kingdom (UK) and United States of America (USA) ranges from 3.7 to 15.3% [9–12]. The mortality rate in our series is at the lower end of this range and similar to data published by the Danish Colorectal Cancer group (3.7%) [10]. Similar to Australia and New Zealand, Denmark, France and the UK provide universal healthcare coverage which is funded by the government through taxation. In comparison, healthcare in the USA is a hybrid multi-payer health system which relies heavily on private healthcare fund. However, uneven private insurance coverage leads to variable access to healthcare system. Our result reflects the high quality of perioperative and surgical care provided by participating surgeons across both nations. Subspecialisation have been shown to improve both short- and long-term surgical outcomes for patients with colorectal cancer in other studies [13, 14].

Social deprivation has been implicated in poorer survival after emergency colorectal cancer surgery based on Surveillance Epidemiology and End Results (SEER) data in the USA [15]. This reflects complex interactions between patient and tumour characteristics, variations in hospital resources and accessibility to healthcare system. We did not identify any significant association between SES and emergency presentation of colorectal cancer. In addition, lower SES and health insurance status were not a predictive factor for inpatient survival in our multivariate analysis. Our findings mirror results from a population study from the Netherland in which the difference in 30-day mortality observed in different SES is no longer significant after adjusting for patient, tumour and surgical factors [16].

The implementation of a colorectal cancer screening program has been shown to be cost effective in reducing cancer-related mortality [17]. Early recognition of colorectal cancer may lead to a reduction in emergency presentation [18]. With the gradual roll-out of colorectal cancer screening program in Australia, the current participation level in the target age group is close to 40%. Further reduction in healthcare expenditure and improvement in colorectal cancer-related mortality are anticipated with increased participation rate as demonstrated in a modelling study and budget impact analysis [19]. Exploring strategies to improve participation rate will be worthwhile in the long term.

Fig. 1 ROC curves of predictive models for inpatient mortality in emergency colorectal cancer surgery



Cancer care pathway driven by national governing body provides recommendations for best practice based on current evidence. However, there is no clear guideline for emergency cancer surgery. The level of emergency cancer care is often locally driven as it is highly dependent on hospital resources and availability of specialists.

Nonetheless, based on our predictive model, it is imperative to minimise postoperative complications to reduce postoperative mortality in this group of high-risk individuals. Perioperative strategies should focus on early resuscitation, followed by prompt surgical care.

In spite of rigorous preventive measures, some of the cardiopulmonary complications are not entirely preventable, as they are common existing comorbidities in the elderly and they are often exacerbated by acute illness and surgical stress. Hence, early recognition and rectification of complications are crucial to minimise the detrimental effect of postoperative complications [20, 21].

In addition to some of the measures mentioned above, Emergency Laparotomy Network in UK also identified a few key areas at organisational level that need to be improved, such as timeliness of radiological investigations, access to emergency theatre, early consultant surgeon and anaesthetist involvement of patient care and postoperative review by physician for patients age > 70 [22].

Strength and limitation

By using a prospective database across two nations, the results obtained from this study provide an accurate representation of

the short-term surgical outcomes of colorectal cancer patients requiring emergency surgery. Nonetheless, it is limited by the nature of voluntary data entry, in which it is likely that the participants are amongst the most motivated surgeons at ensuring that excellent quality of care is delivered to the community. In addition, the current BCCA dataset does not contain specific clinical details such as comorbidities, causes for the emergency presentation (perforation versus obstruction), resuscitation strategies, intensive care unit support and severity of each complications that may influence the short-term outcomes and provide an insight on which specific pathway to improve. Electronic health record is still at its infancy in Australia and New Zealand and continue to mature with increasing uptake. In the future, the BCCA planned to have individual unit auditing to ensure a robust electronic system, with data linkage between hospital and clinical registries, fostering a close collaborative effort to improve patient care.

Conclusion

Postoperative complications have significant impact on short-term survival after emergency colorectal cancer surgery. Disparity in postoperative outcomes after emergency surgery gives impetus to quality improvement programs such as Australia and New Zealand Annual Surgical Mortality audit (ANZASM) and National Emergency Laparotomy Audit (NELA) in UK. Results derived from such programs can provide valuable insights into ways to minimise morbidity and

mortality associated with emergency colorectal cancer surgery.

Acknowledgements We would like to acknowledge and thank the Bi-National Colorectal Cancer Audit and all the surgeons who contribute to the audit, without whom this study would not be possible. We thank Epworth Healthcare for all the support and assistance.

Compliance with ethical standards

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

References

1. Arnold M, Sierra MS, Laversanne M, Soerjomataram I, Jemal A, Bray F (2017) Global patterns and trends in colorectal cancer incidence and mortality. *Gut* 66(4):683–691
2. Ghazi S, Berg E, Lindblom A, Lindfors U, Low-Risk Colorectal Cancer Study Group (2013) Low-risk colorectal Cancer study group. Clinicopathological analysis of colorectal cancer: a comparison between emergency and elective surgical cases. *World J Surg Oncol* 11(1):133
3. Oliphant R, Mansouri D, Nicholson GA et al (2014) Emergency presentation of node-negative colorectal cancer treated with curative surgery is associated with poorer short and longer-term survival. *Int J Color Dis* 29(5):591–598
4. Teixeira F, Akaishi EH, Ushinohama AZ, Dutra T, Netto SDC, Utiyama E, Bernini C, Rasslan S (2015) Can we respect the principles of oncologic resection in an emergency surgery to treat colon cancer? *World J Emerg Surg* 10:5
5. Weixler B, Warschkow R, Ramser M, Droeser R, von Holzen U, Oertli D, Kettelhack C (2016) Urgent surgery after emergency presentation for colorectal cancer has no impact on overall and disease-free survival: a propensity score analysis. *BMC Cancer* 16:208
6. Ireland MJ, March S, Crawford-Williams F, Cassimatis M, Aitken JF, Hyde MK, Chambers SK, Sun J, Dunn J (2017) A systematic review of geographical differences in management and outcomes for colorectal cancer in Australia. *BMC Cancer* 17:95
7. Heriot A, Platell C, Byrne C, et al The Bi-National Colorectal Cancer Audit Report 2017. <http://bccaregistry.org.au>. Accessed 25/4/2018
8. Faiz O, Warusavitarne J, Bottle A, Tekkis PP, Clark SK, Darzi AW, Aylin P (2010) Nonelective excisional colorectal surgery in English National Health Service Trusts: a study of outcomes from hospital episode statistics data between 1996 and 2007. *J Am Coll Surg* 210(4):390–401
9. National Bowel Cancer Audit Annual Report 2016 Version 2. <https://www.acpgbi.org.uk/content/uploads/2016/07/nati-clin-audi-bowe-canc-2016-rep-v2.pdf>. Accessed 25/4/2018
10. Osler M, Iversen LH, Borglykke A et al (2011) Hospital variation in 30-day mortality after colorectal cancer surgery in Denmark. *Ann Surg* 253(4):733–738
11. Ingraham AM, Cohen ME, Bilimoria KY, Feinglass JM, Richards KE, Hall BL, Ko CY (2010) Comparison of hospital performance in nonemergency versus emergency colorectal operations at 142 hospitals. *J Am Coll Surg* 210(2):155–165
12. Panis Y, Maggiori L, Caranhac G, Bretagnol F, Vicaut E (2011) Mortality after colorectal cancer surgery. *Ann Surg* 254(5):738–744
13. Platell C, Lim D, Tajudeen N, Tan JL, Wong K (2003) Dose surgical sub-specialization influence survival in patients with colorectal cancer. *World J Gastroenterol* 9(5):961–964
14. Oliphant R, Nicholson GA, Horgan PG, Molloy RG, McMillan DC, Morrison DS, in collaboration with the West of Scotland Colorectal Cancer Managed Clinical Network (2013) Contribution of surgical specialization to improved colorectal cancer survival. *Br J Surg* 100(10):1388–1395
15. Pruitt SL, Davidson NO, Gupta S, Yan Y, Schootman M (2014) Missed opportunities: racial and neighborhood socioeconomic disparities in emergency colorectal cancer diagnosis and surgery. *BMC Cancer* 14(927)
16. Dik VK, Aarts MJ, Van Grevenstein WMU et al (2014) Association between socioeconomic status, surgical treatment and mortality in patients with colorectal cancer. *Br J Surg* 101(9):1173–1182
17. Hewitson P, Glasziou PP, Irwig L et al (2007) Screening for colorectal cancer using the faecal occult blood test, Hemoccult. *Cochrane Database Syst Rev* (1):CD001216
18. Geraghty J, Shawihdi M, Devonport E, Sarkar S, Pearson MG, Bodger K (2018) Reduced risk of emergency admission for colorectal cancer associated with introduction of bowel cancer screening across England: retrospective national cohort study. *Color Dis* 20(2):94–104
19. Lew JB, St John DJB, Xu XM, Greuter MJE, Caruana M, Cenin DR, He E, Saville M, Grogan P, Coupé VMH, Canfell K (2017) Long-term evaluation of benefits, harms, and cost-effectiveness of the National Bowel Cancer Screening Program in Australia: a modelling study. *Lancet Public Health* 2(7):e331–e340
20. Silber JH, Williams SV, Krakauer H, Schwartz S (1992) Hospital and patient characteristics associated with death after surgery: a study of adverse occurrence and failure to rescue. *Med Care* 30(7):615–629
21. Almoudaris AM, Burns EM, Mamidanna R, Bottle A, Aylin P, Vincent C, Faiz O (2011) Value of failure to rescue as a marker of the standard of care following reoperation for complications after colorectal resection. *Br J Surg* 98(12):1775–1783
22. The Second Patient Report of the National Emergency Laparotomy Audit (NELA) (2016) <http://www.nela.org.uk/Second-Patient-Report-of-the-National-Emergency-Laparotomy-Audit#pt>. Accessed 25/4/18