ORIGINAL CONTRIBUTION

Risk Factors Associated With Circumferential Resection Margin Positivity in Rectal Cancer: A Binational Registry Study

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BACKGROUND: Rectal cancer outcomes have improved with the adoption of a multidisciplinary model of care. However, there is a spectrum of quality when viewed from a national perspective, as highlighted by the Consortium for Optimizing the Treatment of Rectal Cancer data on rectal cancer care in the United States.

OBJECTIVE: The aim of this study was to assess and identify predictors of circumferential resection margin involvement for rectal cancer across Australasia.

DESIGN: A retrospective study from a prospectively maintained binational colorectal cancer database was interrogated.

SETTINGS: This study is based on a binational colorectal cancer audit database.

PATIENTS: Clinical information on all consecutive resected rectal cancer cases recorded in the registry from 2007 to 2016 was retrieved, collated, and analyzed.

MAIN OUTCOME MEASURES: The primary outcome measure was positive circumferential resection margin, measured as a resection margin ≤1 mm.

RESULTS: A total of 3367 patients were included, with 261 (7.5%) having a positive circumferential resection margin. After adjusting for hospital and surgeon volume, hierarchical logistic regression analysis identified a 6-variable model encompassing the independent predictors, including urgent operation, abdominoperineal resection, open technique, low rectal cancer, T3 to T4, and N1 to N2. The accuracy of the model was 92.3%, with an receiver operating characteristic of 0.783 ($p < 0.0001$). The quantitative risk associated with circumferential resection margin positivity ranged from <1% (no risk factors) to 43% (6 risk factors).

LIMITATIONS: This study was limited by the lack of recorded long-term outcomes associated with circumferential resection margin positivity.

CONCLUSIONS: The rate of circumferential resection margin involvement in patients undergoing rectal cancer resection in Australasia is low and is influenced by a number of factors. Risk stratification of outcome is important with the increasing demand for publicly accessible quality data. See **Video Abstract** at http://links.lww.com/DCR/A512.

KEY WORDS: Circumferential resection margin; Quality of surgery; Rectal cancer.

CME

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Rectal cancer outcomes have improved significantly over the last two decades, largely through the adoption of a multidisciplinary model of care, with

accompanying improvements in the quality of surgery. Historically local recurrence rates were as high as 30% in small series[1] and 23% in the control arm of the Swedish rectal cancer trial.[2] Total mesorectal excision (TME), with meticulous dissection in the extrafascial plane to maintain an intact fascial envelope, was popularized in the late 1980s and increasingly adopted as the standard of surgical resection for rectal cancer.[3]

The importance of achieving a clear circumferential resection margin (CRM) in reducing rectal cancer recurrence is well documented.[4] This was emphasized in a large meta-analysis performed by Nagtegaal et al[5] on 17,000 patients, which showed that a CRM of ≤1 mm was a strong predictor of local and distant recurrence. However, a spectrum of surgical quality still remains, as demonstrated by the Consortium for Optimizing the Treatment of Rectal Cancer data in the United States.[6]

In their national database, a positive CRM rate of 17.2% was reported. High-risk patients identified from the data included those with T4 tumors, those with lymph node involvement, and those undergoing proctectomy. Surprisingly the risk was less with a laparoscopic approach.[6] This landmark article showed that 1 in 6 patients received a suboptimal oncological resection, and this result has the ability to alter healthcare practice in the United States.

Furthermore, it is unknown whether hospital location (rural versus urban) or patient socioeconomic status will influence the quality of surgical care. This is of particular importance by way of respecting a patient's choice of having the surgery locally, with familiar and trusted physicians, close social support network, and within an attainable geographical proximity. Irrespective of geographical location or economic status, all patients should have access to good quality surgical care.

There is an increasing government, state-based, and hospital push to measure the quality of cancer care across Australia and New Zealand. Currently, there are limited data on CRM positivity within Australasia, a surrogate marker for the quality of TME. The aim of our study was to assess CRM positivity rates across the Binational Colorectal Cancer Audit (BCCA) and to determine risk factors associated with CRM positivity.

MATERIALS AND METHODS

A prospective binational (Australia and New Zealand) colorectal cancer registry (BCCA) was interrogated. This registry was an initiative of the Colorectal Surgical Society of Australia and New Zealand (CSSANZ) for the purpose of establishing a binational database for quality assurance, audit, and research for all surgeons undertaking colorectal cancer resections. The BCCA is a voluntary clinical quality registry with >200 participating surgeons across Australia and New Zealand from both public and private systems. At least 80% of the participating surgeons are CSSANZ members, who will perform the majority of rectal cancer surgery across Australasia. Participating units extract and submit the data to the central repository using an online system. This electronic system has dropdown boxes and a glossary to ensure consistency of data submission. The comprehensive database has received >15,000 episodes from 85 hospitals since its commencement in 2007. The database represents 20% to 25% of all colon cancer and ≈60% of all rectal cancer cases performed in Australasia. The BCCA registry relies on the participating units to update the clinical, pathology, and long-term outcome data. During the early introduction of the registry (2007–2013), data were complete in 68% of entries. With the introduction of an online system since 2014, with dropdown boxes and reminders of incomplete fields, the completion rate has risen to 79%.

All of the consecutive resected rectal cancer cases from 2007 to 2016 were retrieved, and data on patient demographics, hospital location, socioeconomic status, level of colorectal training (CSSANZ members or general surgeons), tumor staging, treatment details, and pathology were collected. Patient socioeconomic status was derived from their postcode matched with income data from the Australian and New Zealand Government Census database. Low socioeconomic status was defined as postcodes with a low income (mean annual income of $19,500 compared with $51,896 as the mean), low education level, and an unemployment rate within the lowest 20th percentile of the Australasian population. Tumor regression grade was defined as follows: grade 0, complete response with no viable cancer cells; grade 1, moderate response with single cells or small groups of cancer cells; grade 2, minimal response with residual cancer outgrown by fibrosis; and grade 3, poor response with minimal or no tumor killed and extensive residual tumor.

Main Outcome Measures

The primary outcome measure was a positive CRM, defined as a resection margin of ≤1 mm. The CRM was reported by the BCCA as a continuous variable with gradations of 0.1 mm to the margin. For the purpose of univariate analysis, the outcome measure was converted to a dichotomous form.

Statistical Analysis

Univariate analysis was performed to identify significant predictors of a positive CRM. Fisher exact or Pearson χ^2 tests were performed for categorical data and a Student *t* test for continuous data. Hierarchical logistic regression was then performed to identify independent risk factors, simultaneously adjusting for hospital location and surgeon experience. Additional multivariate regression analy-

sis for model development of independent risk factors in CRM positivity was performed using the stepwise selection process and observing the change in log-likelihood ratios, OR, 95% CI, and clinical importance.

The model was validated by performing a bootstrap resampling method. The accuracy of the model was measured using the Hosmer–Lemeshow goodness-of-fit (HLGOF) test and the area under receiver operating characteristics (AU ROC). Discrimination measured as AU ROC was defined as the ability to assign a higher probability of outcome to patients who had CRM positivity compared with those who did not. Calibration was a measure of accuracy, using the HLGOF test, defined as the ability of the model to assign the correct probability of outcome to an individual patient. A $p > 0.05$ was required to show there was no statistical difference between expected and observed outcome. All statistical analysis was performed using IBM SPSS version 22 (IBM Corp, Armonk, NY), and a $p < 0.05$ was deemed significant.

RESULTS

The breakdown of reasons for exclusion of patients from the analysis is outlined in Table 1.

Univariate Analysis

A total of 3367 patients with rectal cancer were identified, with a CRM-positive rate of 7.75% (261 patients). The patient demographics, pathology, and oncological treatment characteristics in accordance with CRM positivity are populated in Table 2.

On univariate analysis, there was no statistical difference seen among non-CSSANZ versus CSSANZ members ($p = 0.898$), urban versus rural ($p = 0.371$), and qualified surgeons versus surgeons-in-training ($p = 0.170$). Interestingly, low socioeconomic status (9.8% versus 6.9%; $p = 0.033$), public patients (9.4% versus 6.1%; $p < 0.001$), and hospital location by state ($p = 0.025$) were statistically significant. There was a wide range of positive CRM rates between different hospital locations by state (4.3%–27.3%).

TABLE 1. Overview of the patients identified in the binational colorectal cancer audit of Australia and New Zealand and reasons for exclusion

Variable	*No.*
No. of patients with rectal cancer	5646
Patients excluded	2279
Reasons for exclusion	
No documentation of CRM	2081
Local excision	41
TEMS/TAMIS	54
Other procedure	45
Duplicates	58
No. of cases included into regression analysis	1581
Final number of cases included	3249

CRM = circumferential resection margin; TEMS = transanal endoscopic microsurgery; TAMIS = transanal minimally invasive surgery.

The operative risk factors associated with a positive CRM include urgent cases (17.3% versus 7.4%) and an open surgical approach (10.0% versus 3.9%). In terms of tumor pathology characteristics, all had a statistically significant association ($p < 0.001$). This was interrelated to response to neoadjuvant chemoradiotherapy, in which 9.6% of minimal to nonresponding tumors had CRM positivity compared with 4.9%. Furthermore, patients were more likely to have a positive CRM if they were T3 to T4 (12.6% versus 1.6%) or N1 to N2 (13.4% versus 4.4%) on pathological staging.

Subanalysis of Urban and Rural Hospitals

In this analysis, key questions regarding the difference in access to preoperative imaging, oncological treatment, and multidisciplinary meetings (MDMs; Table 3) were interrogated. In the urban centers, patients were more likely to receive neoadjuvant chemoradiotherapy (NACRT; 52.2% versus 40.6%; $p < 0.001$) and endorectal ultrasound (7.0% versus 1.7%; $p = 0.0004$), despite similar proportions in TNM staging (shown in Table 4). However, there was an equal proportion of patients who received preoperative MRI ($p = 0.983$). Access to an MDM was not a factor in the rural centers, because a higher proportion of patients (80.1% versus 64.9%; $p < 0.001$) were discussed in a multidisciplinary setting.

Hierarchical Logistic Regression Analysis

Initially all of the significant variables ($p < 0.05$) were included in the hierarchical logistic regression analysis (n = 1581 cases). After adjusting for hospital location by state, public setting, and socioeconomic status, a multivariate regression analysis identified 6 independent risk factors for a positive CRM, which encompassed urgent operations (OR = 1.88), open approach (OR = 1.61), abdominoperineal resection (APR; OR = 1.14), rectal tumor height <8 cm (OR = 1.81), T3 to T4 (OR = 7.62), and positive lymph nodes (OR = 2.02).

Because preoperative MRI, duration of NACRT, tumor regression grade, and adjuvant chemoradiotherapy were not significant from the 1581 cases, the hierarchical logistic regression analysis was repeated by including variables that had <5% missing observations (n = 3249). The same 6 independent variables remained significant. The 6 independent risk factor model had an accuracy AU ROC of 0.783 ($p < 0.001$) and an HLGOF of 92.7% ($p = 0.657$), as demonstrated in Figure 1. These risk factors were validated using a bootstrap resampling method, which showed an AU ROC of 0.765 (95% CI, 0.752–0.781; $p < 0.001$).

The risk factors included in the multivariate regression analysis are listed in Table 5. Neoadjuvant chemoradiotherapy and response to treatment were not independent risk factors after taking into account tumor and operative

TABLE 2. Patient demographics and operative and tumor characteristics

Characteristics	CRM negative, n (%)	CRM positive, n (%)	p
Sex			
Men	1956 (91.9)	173 (8.1)	
Women	1150 (92.9)	88 (7.1)	0.316
Age, y			
<60	1415 (91.1)	138 (8.9)	
≥60	1691 (93.2)	123 (6.8)	0.023
CSSANZ members			
Yes	2894 (92.3)	243 (7.7)	
No	212 (92.2)	18 (7.8)	0.898
Location			
Urban	2738 (92.4)	225 (7.6)	
Rural	368 (91.1)	36 (8.9)	0.371
State			
New South Wales	581 (93.1)	43 (6.9)	
Australian Capital Territory	8 (72.7)	3 (27.3)	
Victoria	981 (95.7)	44 (4.3)	
Queensland	449 (88.9)	56 (11.1)	
South Australia	709 (90.8)	72 (9.2)	
Western Australia	4 (100)	0	
Tasmania	135 (94.4)	8 (5.6)	
Northern Territory	35 (85.4)	6 (14.6)	
New Zealand	204 (87.6)	29 (12.4)	0.025
Socioeconomic status			
Low	416 (90.2)	45 (9.8)	
High	2543 (93.1)	188 (6.9)	0.033
Hospital			
Public	1565 (90.6)	162 (9.4)	
Private	1486 (93.9)	97 (6.1)	
Missing	55	2	<0.001
Operative urgency			
Urgent	86 (82.7)	18 (17.3)	
Nonurgent	2997 (92.6)	239 (7.4)	
Missing	23	4	<0.001
Surgeon seniority			
Consultant	2561 (92.5)	207 (7.5)	
Fellow in training	458 (92)	40 (8)	
Registrar in training	57 (86.4)	9 (13.6)	0.095
Missing	30	5	0.17
ASA score			
I	587 (91.7)	53 (8.3)	
II	1530 (93.1)	113 (6.9)	
III	849 (91.8)	76 (8.2)	
IV	59 (90.8)	6 (9.2)	
V	1 (100)	0	
Missing	80	13	0.315
Tumor height, cm			
Upper (>12)	581 (94.8)	32 (5.2)	
Middle (8–12)	1077 (93.7)	72 (6.3)	
Low (<8)	1448 (90.2)	157 (9.8)	<0.001
Preoperative MRI			
No	688 (94.8)	38 (5.2)	
Yes	1729 (92.2)	147 (7.8)	0.021
Missing	689	76	
Type of surgery			
High anterior resection	147 (96.7)	5 (3.3)	
Low anterior resection	635 (95.2)	32 (4.8)	
Ultralow anterior resection	1438 (94.9)	77 (5.1)	
Proctocolectomy	54 (91.5)	5 (8.5)	
Abdominoperineal resection	612 (85.5)	104 (14.5)	
Hartmann procedure	123 (83.1)	25 (16.9)	
Others	61 (87.1)	9 (12.9)	
Missing	36	4	<0.001
Surgical entry			
Open	1638 (90)	183 (10)	<0.001
Laparoscopic	906 (96.1)	37 (3.9)	
Hybrid	256 (93.8)	17 (6.2)	
Conversion from laparoscopic	159 (92.4)	13 (7.6)	
Robotic	69 (94.5)	4 (5.5)	
taTME	21 (95.5)	1 (4.5)	
Anastomosis formation			
Yes	1431 (96.9)	46 (3.1)	
No	490 (88.1)	66 (11.9)	
Missing	1185	149	<0.001

CSSANZ = Colorectal Surgical Society of Australia and New Zealand; taTME = transanal total mesorectal excision; CRM = circumferential resection margin.

factors. The quantitative risk associated with CRM positivity ranges from <1% (no risk factors) to 43% (6 risk factors).

DISCUSSION

The binational colorectal cancer registry has allowed a comprehensive assessment of surgical quality for rectal cancer resection across Australasia. This study confirms that the Australasian CRM-positive rate of 7.75% is comparable to other reported series,[7–9] and through this database, a 6-variable risk stratification model (urgent operation, open approach, APR, tumor height <8 cm from the anal verge, ypT3 to T4, and ypN+ stage) was developed.

Surgeons are engrained by way of their training to maintain the highest quality and standard of patient care. A tenet of this is the collection of patient data to perform a quality assurance audit.[10] The BCCA database is a platform established to encourage surgeons to enter the minimum data set for colorectal cancer surgical procedures. The quality of rectal resection, which is influenced by multiple factors, was assessed by analyzing this database in sight of the fact that a positive CRM is strongly correlated with local, pelvic, and distant recurrence.[5,9]

The results demonstrate that CRM positivity was significantly higher in public patients (9.4% vs 6.9%)

TABLE 3. Treatment characteristics, postneoadjuvant chemoradiotherapy tumor stage, and surgical complications

Characteristics	*CRM negative*	*CRM positive*	*p*
Neoadjuvant chemoradiotherapy, n (%)			
Yes	1492 (90.4)	158 (9.6)	
No	1500 (93.8)	99 (6.2)	
Missing	114	4	<0.001
Duration of neoadjuvant chemoradiotherapy, n (%)			
Long course	1154 (89.9)	130 (10.1)	
Short course	300 (94.0)	19 (6.0)	
Others	36 (81.8)	8 (18.2)	
Missing	1616	104	0.011
Tumor regression grade, n (%)			
Complete pathological response	228 (100)	0 (0)	
Moderate pathological response	146 (95.4)	7 (4.6)	
Minimal pathological response	236 (94.4)	14 (5.6)	
No pathological response	190 (86.0)	31 (14.0)	<0.001
Good response	374 (98.2)	7 (1.8)	
Minimal to no response	426 (90.5)	45 (9.6)	<0.001
Missing	2311	204	
TNM staging, n (%)			
ypT stage			
0	228 (100)	0 (0)	
1	448 (99.6)	2 (0.4)	
2	765 (97.8)	17 (2.2)	
3	1433 (90.4)	152 (9.6)	
4	193 (69.9)	83 (30.1)	
T1–T2	1452 (98.4)	24 (1.6)	
T3–T4	1626 (87.4)	235 (12.6)	<0.001
Missing	44	2	
ypN stage			
0	2017 (95.6)	92 (4.4)	
1	771 (90.8)	78 (9.2)	
2	301 (77.4)	88 (22.6)	<0.001
Lymph node positivity			
Positive, n (%)	1072 (86.6)	166 (13.4)	
Negative, n (%)	2017 (95.6)	92 (4.4)	<0.001
Mean total lymph node harvest (SD)	15.9 (±8.4)	14.8 (±8.4)	0.052
Mean positive lymph node harvest (SD)	1 (±2.3)	3.4 (±5.3)	<0.001
Missing	17	3	
M stage, n (%)			
0	2843 (93.9)	186 (6.1)	
1	249 (77.6)	72 (22.4)	
Missing	14	3	<0.001
Returned to theater, n (%)			
Yes	254 (92.4)	21 (7.6)	
No	2852 (92.2)	240 (7.8)	0.94
In-patient deaths, n (%)			
Yes	36 (94.7)	2 (5.3)	
No	3070 (92.2)	259 (7.8)	0.564
Adjuvant chemotherapy, n (%)			
Yes	1364 (89.6)	159 (10.4)	
No	26 (89.7)	3 (10.3)	
Missing	1390	162	0.987
Adjuvant radiotherapy, n (%)			
Yes	77 (77.0)	23 (23.0)	
No	1281 (90.4)	136 (9.6)	
Missing	1748	102	<0.001
Total patients, n (%)	3106 (92.3)	261 (7.6)	3367

CRM = circumferential resection margin.

and those with a low socioeconomic status (9.8% vs 6.1%). On face value, concerns may be raised that inequality of care exists; however, multivariate regression analysis has revealed that the key risk factors associated with CRM positivity are operative and tumor factors. A simple explanation is that these variables were adjusted for by taking clustering effects into account.[11] For example, patients treated from the same hospital are grouped as 1 cluster because they share a similar quality of care. Using this methodology, statistically significant independent risk factors for CRM positivity were identified.

Furthermore, concerns were raised about the disparity of oncological care in the rural setting.[12] Factors that can influence survival outcomes among rural patients include later tumor stage at diagnosis, limited access to treatment facilities, and socioeconomic disadvantage.[13,14] In the BCCA registry, 404 patients (12.0%) had their TME in 24 participating rural hospitals, and the positive CRM rate was 8.9%. This was higher than the rate in the urban centers (7.6%) but did not reach statistical significance. This finding can be explained by equal access to MRI, a higher proportion of patients in the rural regions being discussed at an MDM, and similar proportions of TNM staging. There is a potential bias, however, because the registry is voluntary, and it is therefore impossible to determine the true denominator between urban and rural patients. The BCCA database is also biased toward CSSANZ-trained surgeons, representing 80% of the cases in the rural cohort. Comparison is made with a population study from Arizona, which showed a significantly higher proportion (72.6%) of stage IV disease among rural patients compared with their urban counterparts (21.6%) and which was vastly larger than that reported in the BCCA database (8.5%).[14] Hence, it is likely that the rural CRM positivity may be higher than currently analyzed by the BCCA data because of a myriad of limitations, such as underreporting and lack of participation by general surgeons. The current observed results can only be interpreted as data driven by CSSANZ-trained surgeons in both urban and rural regions.

Moreover, using this database allowed for the creation of a risk-adjusted model, not only for audit purposes to compare like with like but also to generate an objective

TABLE 4. Comparison between urban and rural patients receiving rectal cancer resection

Variables	*Urban*	*Rural*	*p*
Total hospitals, n (%)	61 (71.8)	24 (28.2)	
Socioeconomic status, n (%)			
Low	205 (7.3)	34 (8.8)	
High	2599 (92.7)	354 (91.2)	0.3
Missing	159	16	
CSSANZ members, n (%)			
No	152 (5.1)	78 (19.3)	
Yes	2811 (94.9)	326 (80.7)	<0.001
Preoperative MRI, n (%)			
No	648 (27.9)	78 (28.0)	
Yes	1675 (72.1)	201 (72.0)	
Missing	640	201	0.983
Preoperative ERUS, n (%)			
No	1808 (93.0)	173 (98.3)	
Yes	137 (7.0)	3 (1.7)	
Missing	1018	228	0.004
NACRT, n (%)			
No	1360 (47.8)	239 (59.5)	
Yes	1487 (52.2)	163 (40.6)	<0.001
MDM discussion, n (%)			
No	678 (35.1)	35 (19.9)	
Yes	1236 (64.9)	140 (80.1)	
Missing	1049	229	<0.001
T stage, n (%)			
0	207 (7.1)	21 (5.3)	
1	407 (13.9)	43 (10.9)	
2	685 (23.4)	97 (24.5)	
3	1387 (47.4)	198 (50.0)	
4	239 (8.2)	37 (9.3)	
Missing	38	8	0.264
N stage, n (%)			
0	1872 (63.5)	237 (59.4)	
1	744 (25.2)	105 (26.3)	
2	332 (11.3)	57 (14.3)	
Missing	15	5	0.145
Mean total LN	15.81	15.72	0.849
Mean total positive LN	1.18	1.43	0.11
M stage, n (%)			
0	2662 (90.3)	367 (91.5)	
1	287 (9.7)	34 (8.5)	
Missing	14	3	0.424
Adjuvant chemotherapy, n (%)			
No	27 (2.0)	2 (1.1)	
Yes	1345 (98.0)	178 (98.9)	0.393

CSSANZ = Colorectal Surgical Society of Australia and New Zealand; ERUS = endorectal ultrasound; NACRT = neoadjuvant chemoradiotherapy; MDM = multidisciplinary meeting; LN = lymph node.

risk calculator for CRM positivity.[15,16] In the risk model, open procedure was an independent risk factor, with a CRM-positive rate of 10.0% compared with 3.9% for the laparoscopic approach ($p < 0.001$). This was equivalent to findings in the Comparison of Open Versus Laparoscopic Surgery for Mid or Low Rectal Cancer After Neoadjuvant Chemoradiotherapy trial (3% CRM rate) but in conflict with those quoted in Australasian Laparoscopic Cancer of the Rectum trial, with a CRM positivity of 7% in the laparoscopic versus 3% for the open approach.[17] The authors of the Australasian Laparoscopic Cancer of the Rectum trial explained that, because the laparoscopic approach did not show noninferiority, cautious consideration should be undertaken, and that patient selection is critical in selecting the most suitable candidate for the approach. Other randomized trials have also shown higher positive CRM rates, including 10.0% from COLOR II and 12.1% from Z6051.[18,19]

Other risk factors, such as urgent surgery, APRs, ypTN stage, and tumor height from the anal verge, have all been consistently documented as predictors of a positive CRM.[1,8,20,21] It is not surprising that APR was identified as an independent risk factor within this model, given the technical challenges encountered as the mesorectum narrows in the distal rectum, compounded by the narrowing pelvis, as has been identified in the United Kingdom with the resulting Low Rectal Cancer study.[22] Furthermore, ypTN stage is likely significant because of the lack of tumor downstaging after NACRT, indicating an inherently unfavorable tumor biology that is resistant to treatment. Coupled with the radiation effects creating a more difficult operative field, the increased CRM positivity rate is not unexpected.

Lastly, an objective risk calculator will aid in patient consent and possibly change the initial treatment plan.[16] An example would be the restaging of a primary tumor after NACRT to gauge response and consider increasing the duration of chemotherapy, administering a preoperative radiotherapy boost, or extending the surgical resection in the case of a limited tumor response.[23] The value of a risk calculator was assessed recently in a randomized trial, and the results confirmed that the use of a modeling system can influence a surgeon's assessment of risk, leading to a change in decisions on a patient's treatment plan.[24]

Although the strength of this study lies in the number of patients included in the regression model, providing significant power and robustness so that it can be applied easily across Australasia, there are several limitations. Data collection to the audit is voluntary and in a number of cases incomplete, hence, although providing a perspective on CRM involvement across Australasia, it is not comprehensive and may not be a true representation of positive CRM rates in Australasia. Second, this study cannot indicate the proportion of participating surgeons who submit all of the consecutive cases, because currently there is no periodic audit to assess data accuracy in each participating unit because of resource constraints, although there is intention to implement this in the future. Third, long-term outcomes were not routinely recorded by surgeons, therefore the implications of a positive CRM will not be known. Fourth, the authors acknowledged that major contributors to the database (both rural and urban regions) were CSSANZ-trained surgeons, and current results will need to be interpreted with a high level of cau-

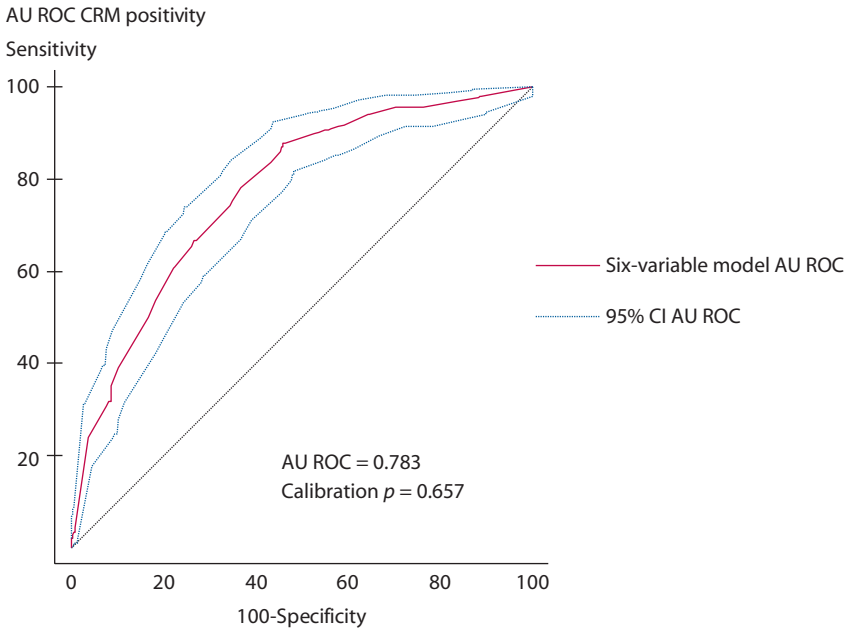

FIGURE 1. The 6-variable model area under the receiver operating characteristic (AU ROC) and confidence interval for circumferential resection margin (CRM) positivity in rectal cancer.

TABLE 5. Six-variable model characteristics

Variable	*p*	*OR*	*95% CI*
Hospital factors			
Public vs private	0.452	1.21	0.77–1.91
Location by state	0.199	1.10	1.01–1.19
Patient factors			
Age ≥60 y	0.384	1.22	0.78–1.94
Low socioeconomic status	0.185	1.90	1.20–3.01
Neoadjuvant therapy			
Chemoradiotherapy administered	0.155	1.17	0.65–2.11
Limited or no response	0.9682	1.01	0.65–1.57
Operative factors			
Urgent operations	0.001	1.88	1.05–3.37
Open approach	<0.001	1.61	1.18–2.20
Abdominal perineal resections	<0.001	1.14	1.03–1.26
Tumor factors			
Tumor height <8 cm	<0.001	1.81	1.34–2.45
T3–T4	<0.001	7.62	4.67–12.42
Lymph node positive	<0.001	2.02	1.50–2.71

Analysis	*Value*	*95% CI*	*p*
AU ROC	0.783	0.768–0.797	<0.001
HLGOF (% accuracy)	92.7	NR	0.657
Bootstrap AU ROC, 10,000 samples	0.765	0.752–0.781	<0.001

AU ROC = area under receiver operating characteristics; HLGOF = Hosmer–Lemeshow goodness-of-fit test; NR = not rated.

tion. Finally, the accuracy of a risk calculator is inherently driven by the data that it was derived from, and recalibration may be required over time, especially with the improvement in quality of care.[16]

CONCLUSION

The rate of CRM involvement in patients undergoing rectal cancer resection in Australasia is low and is influenced by a number of factors, including data being biased toward CSSANZ-trained surgeons. Risk stratification of outcome allows a fair comparison between hospitals and surgeons of different states, and this is important with the increasing demand for publically accessible quality data.

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