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**Abdominoperineal Resection in Australasia: Clinical Outcomes, Predictive Factors, and Recent Trends of Non-Restorative Rectal Cancer Surgery**

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**Keywords:** Abdominoperineal Resection, Adenocarcinoma, Restorative Resection, Predictive Factors, Circumferential Resection Margin

**Abstract**

**Aim:** The decision to perform an abdominoperineal resection (APR) over restorative bowel resection relies on a number of clinical factors. There remains great variability in APR rates internationally. The aim of this study was to demonstrate trends of APR surgery in low rectal cancer (<6cm) in Australasia and identify predictors of non-restoration.

**Methods:** A review of a prospectively maintained colorectal registry- the Binational Colorectal Cancer Audit(BCCA) from General/Colorectal Surgical Units across Australia and New Zealand. Data were analysed to determine factors predictive of non-restorative resection. Patients were analysed based on the presence (control) or absence (comparison) of a primary anastomosis.

**Results:** Of 3628 patients with rectal cancer, 2096 patients were diagnosed with low rectal cancer between 2007 and 2017. The incidence of APR remained constant over the study period with 58% of all low rectal cancer resections undergoing APR. The majority of resections were performed by consultants in urban hospitals (86%v14%). Tumours at or less than 3cm from anal verge, T4, M1 disease and neoadjuvant therapy were the greatest predictors of APR ($p<0.001$). A significantly increased rate of restorative surgery was observed in the public hospital setting (59%v41%, $p<0.05$). CRM positivity was 7.95% with significantly increased rates in patients undergoing APR (12.2%v6.2%, $p<0.001$). CRM was increased in open approaches, T4, N2 and M1 staged disease and in an emergency/urgent setting ($p<0.001$,0.045 respectively). Significantly increased wound and pulmonary complications were observed in the APR cohort($p<0.01$).

**Conclusion:** The rates of APR in Australia and New Zealand remain high but comparable internationally with one third of rectal cancers undergoing APR. The main determinants of APR are tumour height, T stage and neoadjuvant therapy requirement. CRM positivity was higher in APR patients.

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**Introduction:**

With recent advances in surgical technique and technology, the last thirty years have demonstrated a trend toward the adoption of restorative bowel resection with low colorectal or coloanal anastomosis in patients who previously would have undergone an abdominoperineal resection (APR) as described by Miles[1]. The increased utilisation of TME dissection, improved preoperative imaging and advent of the circular endoluminal stapling devise has increased restoration rates where possible. In addition, the acceptance of an oncological distal margin of at least 1cm has led to a greater propensity to perform distal rectal resection with a low restorative colonic anastomosis. This has resulted in less abdominoperineal resections being performed, with some studies showing a decrease from around one third of rectal cancer cases in the 1990s to less than 12% by 2011[2, 3].

There are ongoing concerns regarding the quality of resection and oncological outcomes when performing APR and its impact on long-term survival. In 2011 the OSTRiCh Consortium highlighted the considerable variability that exits in rectal cancer outcomes across the United States[4]. It was demonstrated that rates of resection along with quality of resection differed according to geographic location, the availability of colorectal specialist expertise, and whether operations were performed in tertiary urban centres versus rural hospital settings. Similar findings were demonstrated in the UK LOREC Program[5]. For these reasons, some have argued that the rates of APR being performed could be seen as a surrogate marker of overall surgical service and quality[6,7].

The incidence and epidemiological trends of APR across Australasia are not currently known. It is also not known what precise factors are predictive of whether a patient has an APR as opposed to a low or ultralow anterior resection. Likewise, information is lacking with regard to the overall pathological and oncological equivalence between these two operations.

This study therefore aims to investigate the trends of APR across Australia and New Zealand by analysing real world data obtained from a cancer registry audit, and to delineate which epidemiological and clinical factors are most predictive of non-restoration, and/or poor pathological outcome. In this manner we hope to provide an overall snapshot of the treatment of low rectal cancer as it pertains to Australia and New Zealand currently.

**Methods:**

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Prospectively collected data from the Bi-National Colorectal Cancer Audit (BCCA) registry were analysed. Data inserted into the BCCA registry are collated prospectively pertaining to surgically managed colorectal cancer from over 400 colorectal surgeons across both Australia and New Zealand. First established in 2007 as a clinical audit tool it represents a prospectively maintained register of over 30,000 anonymised treatment episodes. The Colorectal Surgical Society of Australia and New Zealand (CSSANZ) is currently the only accredited colorectal authority body in Australasia and all member colorectal surgeons are required to record their cancer cases in the BCCA database. Despite this there are a large number of general and non-accredited colorectal surgeons practicing within this domain who are not required to and do not record data in the BCCA registry. Data from 29 individual data points ranging from basic demographic data and procedural dates are inserted by both clerical and varying levels of clinical staff. Operative and outcome data points are inserted by the operating colorectal service. Emergent intervention is also included which accounts for approximately 15% of cases recorded. Data analysed for research purposes is anonymised for country, district and treating hospital. Participation is available to both Colorectal and General Surgeons performing rectal resections for cancer. Participation rates by jurisdiction in 2018 ranged from 100% in Western Australia, Northern Territory and Tasmania with reduces rates reported in Queensland (72%), New south Wales (79%), Victoria (78%) and in South Australia (79%).

For this study all low rectal cancer cases were identified between 2007 to 2017. Low rectal cancer was defined as an adenocarcinoma extending from 0 to 6cm from the anal verge. Tumour height was individually assessed by the surgeon's own preferred method, although the method (endoscopic, radiological or clinical) of measurement was not specifically recorded within the registry. The reasons for exclusion are presented in Figure 1. Patients were analysed based on the presence (control) or absence (comparison) of a primary anastomosis, and categorised according to whether they underwent either a low/ultralow anterior resection (L-/-ULAR) or an abdominoperineal resection (APR). Data obtained from the registry included; patient factors (sex, age, country, ASA score), hospital factors (geographic location; metropolitan vs. rural locale), public vs. private (whereby public refers to Governmental-run hospital facilities directed by the universal national healthcare program), tumour characteristics (pre-operative staging, TNM stage) and operative factors (Consultant vs. non-Consultant/Trainee, operative urgency-elective vs. emergent/urgent surgery, operative entry (open, laparoscopic, hybrid, robotic), type of surgery, type of reconstruction, type of stoma), as well as the presence or absence of neoadjuvant chemoradiation therapy. Urban/metropolitan location was defined as an Australasian metropolitan region, including tertiary and district hospitals that were principally located in the State capital cities. Rural was defined as remote non-metropolitan centres and regional hospitals. Likewise 'public' hospital refers to Governmental-run hospitals belonging to the National Health Insurance System (Medicare) as opposed to private hospital institutions which are profit and non-profit medical organisations.

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The primary outcomes measured were independent predictors for APR. Secondary outcomes measured were oncological safety of APR, measured by circumferential resection margin (CRM) positivity and post-operative complications. By investigating the proportion of restorative to non-restorative resections over the 10-year study period, the overall rate and recent trends of APR was elucidated.

A univariate analysis consisting of Fisher's exact test or Pearson's chi-squared test was performed to identify significant predictors for APR. This was followed by a stepwise multivariate logistic regression analysis identifying significant independent predictors. All analyses were performed through IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. A p-value of <0.05 was considered significant.

Ethics approval for this project was obtained from the Epworth Healthcare Ethics Committee-EH2018-320, 23/5/18.

**Results**

From the database, 3628 patients were diagnosed with rectal cancer, of whom 1532 were excluded from analysis (Figure 1). Demographic details of 2096 patients (1570 Australia, 526 NZ) demonstrated that approximately two thirds of all rectal cancer patients were male (p<0.05, Table 1). APR represented approximately 58% of the all the operations performed for low rectal cancer (<6cm from anal verge), and 34% of all rectal cancers. There was no significant difference observed between the operations performed based on gender, country or urban versus regional setting. A significant proportion of low rectal cancer operations were performed in an urban setting (86% v 14%, p<0.0). Furthermore, a significant proportion of resections with anastomosis were performed in public institutions (59% v 41%, p<0.05). Similarly, increased rates of APRs were also seen in public institutions (68% vs 31%, p<0.01). The majority of cases were performed by a consultant surgeon followed by surgical fellows (84% v 13%, p<0.01).

The clinical and pathological characteristics of APR and LAR were collated (table 2). Preoperative MRI imaging was similar between both groups, with a higher percentage of restorative procedures having endoscopic rectal ultrasound (8.1%vs 3.8%, p<0.001) prior. The majority of LARs performed were for rectal tumours at a height between 4 and 6cm from the anal verge, while APRs were performed for cancers at or below 3cm from the anal verge. Tumour height was a major predictor of whether a patient undergoes a restorative or non-restorative bowel resection (p<0.01). Another important determinant of non-restoration was T stage. The majority of patients were diagnosed with T2/T3 disease. With regards to T4 low rectal tumours, 73% of patients underwent an APR whilst 27% of patients had a LAR performed (p<0.001). The proportion of lymph node involvement were equally distributed between both procedures. In the presence of metastatic disease there was a significant increase number of APRs performed (5.5% v 9.0%, p<0.01). Almost all low rectal cancers were

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operated on in an elective fashion (97% v 3%). In emergent surgery there was no significant difference in APR v restorative surgery rates (3.0% vs. 1.6%, p=0.077). Neoadjuvant therapy was also associated with increased rates of APR (68% to 60%).

Surgical strategy differed between the two groups. In the LAR group, 24.9% were performed laparoscopically and 40% via an open technique-the remaining performed either by hybrid format (9.9%), laparoscopic converted to open procedure (3.9%), traditional transanal dissection (11.4%), TaTME (4.9%), and robotic (4.7%) A significantly increased rate of open surgery was encountered in patients undergoing APR (64.4%, p<0.01). Conversion rates to open were similar between both groups. Circumferential resection margin (CRM) positivity differed between the two procedures with 12.2% involvement for patients undergoing APR and 6.2% for patients receiving a LAR (p<0.001). Circumferential margin status was then correlated with the demographic and clinicopathological data to determine the predictive factors which were associated with APR and positive CRM (table 3). The overall positive CRM rate for APR for both restorative and non-restorative resection was 7.95%. Factors predicting CRM positivity were procedures performed in a private institution setting (p<0.034), open surgical approach (p<0.001), T4 stage (p<0.001),N2 stage (p<0.001), and M1 staged disease (p<0.001) and in cases where procedures were performed in an emergency and urgent setting (p<0.045).

Independent risk odds ratio for key determinants of APR and CRM positivity are presented in table 4. Advanced T stage (T4 disease) and tumours at or less than 3cm from anal verge were found to be independent predictors for requiring an APR. Advanced T stage was found to be significantly predictive of CRM positivity in patients undergoing rectal cancer surgery in this series (p<0.001).

Post-operative complications between LAR and APR are shown in table 5. There were significantly increased complications encountered in the APR patient cohort (42.1% v 27.8%, p<0.001). An increased rate of superficial and deep wound infections was observed in patients undergoing APR (8.4% vs. 0.8%, 3.5 v 0.8, p<0.01). Post-operative pulmonary infections were also more common in the APR group (4.8% v 2.4%, p<0.005) Deep pelvic collections, DVT/PE, cardiac complications, haemorrhage, return to theatre, ileus and urinary retention were proportionally similar between the two procedures.

The frequency and trends of restorative vs. non-restorative resection for low rectal cancer in Australia and New Zealand from 2007 to 2018 are demonstrated in Figure 2. These rates do not correlate directly with overall prevalence of these operations during this period but rather the cumulative reporting as represented by the BCCA registry. Nevertheless, the trend between restorative and non-restorative resection can been seen to be relatively constant over the study period.

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## Discussion

Tumour stage, metastatic disease and a low rectal tumour height were identified as the main predictors of APR. Increasing T stage was associated with nonrestorative surgery, with T4 status being an independent predictor. These factors are not surprising and are recognised risk factors for predicting non-restoration for low rectal cancers[8]. Lymph node involvement however was not correlated with prediction of non-restoration. Other important determinants of non-restoration, derived from our analysis, were elective versus non-elective/emergent surgical settings, as well as the use of preoperative neoadjuvant chemoradiation therapy. According to our results, APR is still the most common operation performed for low rectal cancer across Australia and New Zealand, with 58% of tumours, < 6cm from the anal verge, undergoing APR. There were similar rates occurring between both countries, urban and rural populations and males and females. Slightly more restorative bowel resections are being performed privately, and reasons for this are not specifically accounted for from these data.

The overall rate of APR to restorative rectal resection was relatively high but comparable to recent population-based studies with approximately 1/3 of all rectal cancer resections undergoing APR. Incidence of APR for rectal cancer varies in the literature and ranges from 18% to 37%[3,9-12]. Moreover, there have been reported instances of much higher APR rates in specific populations[13]. The proportion of APR to restorative resection over the study's time period 2007 to 2017 remained relatively constant, however the total number of both increased over the years, presumably reflecting increased data entry into the Registry. It has been advocated that APR rates could reflect overall quality of surgical service. Studies have demonstrated that APR rates are higher in areas of low socioeconomic status and that social depravation itself is an independent risk factor for APR[2,7]. Within the current study APR was more commonly performed in public hospital setting (62% vs. 52%, $p<0.001$), where public hospitalization could be potentially interpreted as a surrogate marker of socioeconomic status.

One of the main findings from this study is the higher percentage of CRM positivity associated with APR in comparison to restorative bowel resection (12.2% to 6.2%). The rates of CRM positivity with APR are relatively low compared to other studies, although great variability exists, with studies reporting rates ranging from 17%-49%[14, 15]. It is now well recognised that CRM positivity is correlated with higher rates of local recurrence, higher rates of systemic recurrence and reduced disease-free and overall survival[16, 17]. A recent study analysing rectal cancer outcomes in Australia has demonstrated an overall average CRM positivity rate of 7.75%[18]. Given the substantially higher CRM positive rates related to APR as indicated from this study, there may be reasons for concern regarding the overall oncological safety and effectiveness of APR in comparison to LAR. Increased CRM positivity in APR has been attributed to higher T stage involvement, local lymphatic

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involvement, prior neoadjuvant radiation treatment, as well as operating in a difficult and somewhat unfamiliar operating plane[19]. There are also higher rates of intraoperative tumour perforation and plane disruption[15]. This study has indeed demonstrated higher CRM positivity associated with advancing T stage and decreasing tumour height. It has also been demonstrated that these are independent predictors of APR in their own right[8]. Other studies have also shown significant correlation between advancing T stage, N status, and the need for open surgery as risk factors for positive CRM status in all rectal cancers[8].

In recent years an extralevator APR (ELAPE) has been suggested and popularised as an appropriate surgical approach to overcome the anatomical and pathological shortcomings of low rectal cancer[20]. This technique allows for better radial margins, reduced CRM rates, reduced risk of narrowing of the specimen and lower intraoperative perforation rates. Extralevator excision however may carry the risk of increased morbidity given the more complex perineal wound defects with long-term data on overall survival still lacking[20]. In our analysis, higher T stage, lower tumour height, surgical urgency, and neoadjuvant therapy were positive risk factors for both APR and for CRM positivity. The most important risk factors for CRM positivity however were T4 stage, tumour height at or below 3cm and local lymph node involvement. Perhaps with this information, it could be postulated that certain 'high risk' patients are more suitable for extra-levator excision and would be likely to benefit in terms of oncological resection and CRM clearance[21]. In the U.K. the Low Rectal Cancer Development Program (LOREC) was instituted to improve national rectal cancer performance[22]. This led to a widespread standardisation of management and overall improved outcomes. A recent review showed that after the institution of LOREC, ELAPE rates correspondingly increased. The involved CRM rate was still relatively high (13%) compared to non-APR surgery (4%), but there were negligible differences in morbidity or perineal wound complications[23]. The rate of ELAPE to 'standard' APR was not identified from the data collected in this study. Collecting this information may therefore be beneficial in future studies in order to address some of these questions and to observe the impact and preponderance of ELAPE in the Australasian setting.

There are a number of limitations to this study. The BCCA database of the CSSANZ is a voluntary entry database. Since CSSANZ-certified Colorectal Surgeons represent a majority of BCCA participants, BCCA data lacks operative outcomes from general surgeons performing rectal cancer surgery. Individual case volume is lacking and therefore it is difficult to derive conclusions as to whether the number of APRs being performed in a practice affects quality, or whether centralisation of practice is supported. A further limitation of this study, and the data that contributed to it, is that a proportion of the data were not recorded by contributing participants and these 'missing data' makes the drawing of overall conclusions more difficult. As with many international/national databases; despite large patient numbers, missing data points are one of the shortcomings of the registry. There are some data points missing that are not possible to retrospectively insert or manually search for

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within the registry. The missing data directly translates to data sheets not entered into the registry by the participating surgeon/data entrant. It is therefore impossible to analyse systemic differences in patient data that is not uploaded. For example, we concluded with the available data, that low tumour height was a significant predictive factor for non-restoration, however in 43% of cases the tumour height was unknown or not recorded. Furthermore the registry lacks uniformity in the data variables across institutions or participating surgeons. For example, when measuring height of tumour from the anal verge, there is no information on what method is used to determine tumour height, whether that be clinical or endoscopic assessment or on MRI. Although these data examined the clinicopathological outcomes of APR and restorative resections in Australasia, it does not have data on long-term recurrence rates or overall survival as these outcomes are not currently recorded in the BCCA Registry. However, some demographic and epidemiological conclusions can be made from these data regarding the management of low rectal cancer in Australasia. For example, it was demonstrated that rates of APR were similar across urban and rural communities in both countries, regardless of the broad socioeconomic and epidemiological lacking. It has been suggested in previous studies that rates of APR and end-colostomy can be used a surrogate marker of overall quality of surgical service. There is insufficient data in this analysis to make such a conclusion on this point. The findings show that there may be opportunities to standardise and improve the care of patients with low rectal cancer in Australasia. This study provides, to date, the largest real-life 'snapshot' in Australia and New Zealand as it pertains to the clinical and operative management of low rectal cancer.

**Conclusions**

The rates of APR in Australia and New Zealand are high but comparable with other population-based studies with one third of all rectal cancers undergoing APR, and with no discernible change in the proportion of restorative to non-restorative resection of low rectal tumours over the last decade. The main determinants of APR are tumour height and T stage. A significantly increased proportion of restorative procedures are performed in public institutions. CRM positivity is higher in APR patients. These data have potential implications for quality assurance for surgical services as well as potential implications for assessing surgical training.

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**Tables and Figures:**

Figure 1. Included/Excluded Patient Numbers and Reasons for Study Exclusion

Figure 2. APR + ULAR Operations Performed 2007-2018 for Low Rectal Cancer

Table1 Demographic Data on Restorative vs. Non-Restorative Resection

Table 2. Clinicopathological Characteristics of Restorative vs. Non-Restorative Resection

Table 3. Factors Predicting CRM Positivity

Table 4. Post-Operative Complications for Restorative vs. Non-Restorative Resection

Table 5. Predictive Ratios for APR and CRM Status

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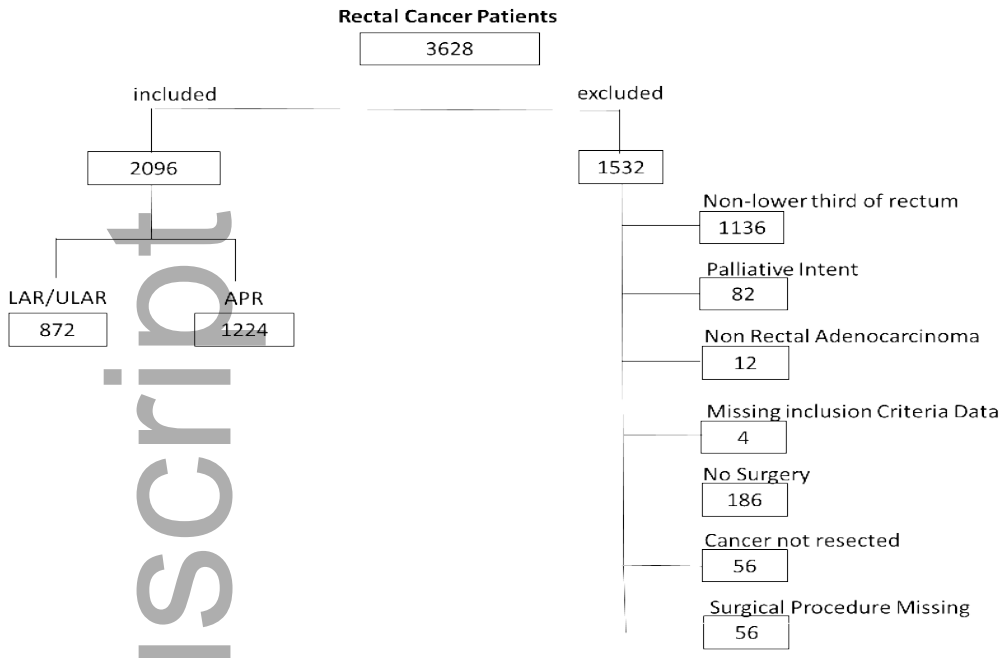
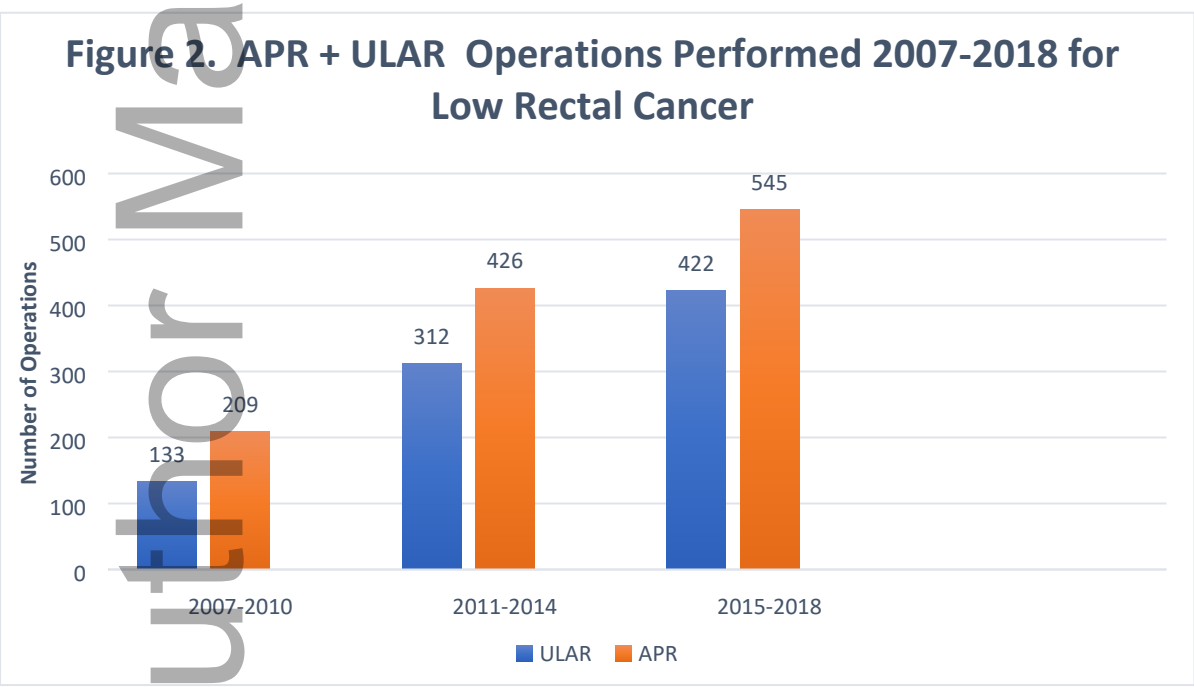



Figure 1. Included/Excluded Patient Numbers and Reasons for Study Exclusion




| Variables | Resection with anastomosis n (%) | APR n (%) | p-value |
|---|---|---|---|
| TOTAL | n=872 | n=1224 | |

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| | | | |
|---|---|---|---|
| ***Sex*** | | | |
| Male | 563 (64.6) | 787 (64.3) | |
| Female | 309 (35.4) | 437 (35.7) | 0.926 |
| ***Country*** | | | |
| Australia | 648 (74.3) | 922 (75.3) | |
| New Zealand | 224 (25.7) | 302 (24.7) | 0.609 |
| ***Hospital Location*** | | | |
| Urban | 751 (86.1) | 1055 (86.2) | |
| Rural | 121 (13.9) | 169 (13.8) | 1.000 |
| ***Hospital Setting*** | | | |
| Public | 511 (59.0) | 835 (68.4) | |
| Private | 355 (41.0) | 385 (31.6) | <0.001 |
| **Operating Surgeon** | | | |
| Consultant | 737 (86.6) | 988 (82.1) | |
| Fellow Supervised | 93 (10.9) | 179 (14.9) | |
| Fellow Unsupervised | 5 (0.6) | 10 (0.8) | |
| Registrar Supervised | 16 (1.9) | 26 (2.2) | 0.054 |
| ***ASA Score*** | | | |
| I | 178 (20.8) | 146 (12.4) | |
| II | 463 (54.0) | 599 (50.7) | |
| III | 196 (22.9) | 415 (35.1) | |
| IV | 19 (2.2) | 21 (1.8) | |
| V | 1 (0.1) | 1 (0.1) | <0.001 |

| Variables | Resection with anastomosis n (%) | APR n (%) | p-value |
|---|---|---|---|
| **TOTAL** | n=872 | n=1224 | |
| ***Preoperative Imaging Modality*** | | | |
| MRI | 692 (81.3) | 792 (81.9) | 0.762 |
| ERUS | 69 (8.1) | 30 (3.8) | <0.001 |
| CT | 299 (36.5) | 280 (36.8) | 0.917 |
| ***Tumour Height*** | | | |
| 0 | 16 (1.8) | 49 (4.0) | |
| 1 | 17 (1.9) | 71 (5.8) | |
| 2 | 44 (5.0) | 142 (11.6) | |
| 3 | 79 (9.1) | 164 (13.4) | |
| 4 | 140 (16.1) | 147 (12.0) | |
| 5 | 264 (30.3) | 80 (6.5) | |
| 6 | 312 (35.8) | 43 (3.5) | |
| Unknown | 0 | 528 (43.1) | <0.001 |
| ***Pathology*** | | | |
| ***T Stage*** | | | |
| 0 | 97 (11.1) | 107 (8.7) | |
| In situ | 8 (0.9) | 3 (0.2) | |
| 1 | 160 (18.3) | 105 (8.6) | |

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| | | | |
|---|---|---|---|
| 2 | 210 (24.1) | 287 (23.4) | |
| 3 | 284 (32.6) | 520 (42.5) | |
| 4 | 33 (3.8) | 124 (10.1) | |
| Unknown | 80 (9.2) | 78 (6.4) | <0.001 |
| ***N Stage*** | | | |
| 0 | 471 (54.0) | 759 (62.0) | |
| 1 | 200 (22.9) | 285 (23.3) | |
| 2 | 65 (7.5) | 106 (8.7) | |
| Unknown | 136 (15.6) | 74 (6.0) | 0.51 |
| ***M Stage*** | | | |
| 0 | 619 (71.0) | 924 (75.5) | |
| 1 | 48 (5.5) | 110 (9.0) | |
| Unknown | 205 (23.5) | 190 (15.5) | 0.01 |
| ***Neoadjuvant Therapy*** | | | |
| Yes | 513 (60.0) | 788 (68.0) | |
| No | 342 (40.0) | 370 (32.0) | <0.001 |
| Unknown | 83(3.9%) | | |
| ***Operative Urgency*** | | | |
| Emergency | 3 (0.3) | 6 (0.5) | |
| Urgent | 26 (3.0) | 19 (1.6) | |
| Elective | 842 (96.7) | 1193 (97.9) | 0.077 |
| ***Surgical Entry*** | | | |
| Open | 350 (40.2) | 765 (64.4) | |
| Laparoscopic | 217 (24.9) | 306 (25.8) | |
| Hybrid | 86 (9.9) | 49 (4.1) | |
| Conversion to open | 34 (3.9) | 37 (3.1) | |
| Robotic | 41 (4.7) | 30 (2.5) | |
| Transanal | 99 (11.4) | 0 | |
| taTME | 43 (4.9) | 1 (0.1) | <0.001 |

| **Variables** | **Resection with anastomosis n (%)** | **APR n (%)** | **p-value** |
|---|---|---|---|
| **TOTAL** | n=872 | n=1224 | |
| ***Reconstruction Method*** | | | |
| Colonic pouch | 200 (34.1) | 0 | |
| Coloplasty | 13 (2.2) | 0 | |
| End-side | 92 (15.7) | 0 | |
| Straight end-end anastomosis | 282 (48.0) | 0 | |
| ***Overall Stage*** | | | |
| 0 | 91 (11.7) | 92 (8.6) | |
| 1 | 291 (37.4) | 287 (26.8) | |
| 2 | 117 (15.0) | 285 (26.7) | |
| 3 | 218 (28.0) | 293 (27.4) | |
| 4 | 46 (5.9) | 101 (9.4) | |
| Missing | 15 (1.9) | 11 (1.0) | <0.001 |
| ***CRM*** | | | |
| Negative | 710 (93.8) | 862 (87.8) | |
| Positive | 47 (6.2) | 120 (12.2) | <0.001 |
| Missing | 357 (17%) | | |

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| Variables | CRM -ve n (%) | CRM +ve n (%) | p-value |
|---|---|---|---|
| ***Sex*** | | | |
| Male | 1241 (91.9) | 109 (8.1) | |
| Female | 688 (92.2) | 58 (7.8) | 0.866 |
| ***Country*** | | | |
| Australia | 1446 (92.1) | 124 (7.9) | |
| New Zealand | 483 (91.8) | 53 (8.2) | 0.853 |
| ***Hospital Location*** | | | |
| Urban | 1659 (93.1) | 147 (6.9) | |
| Rural | 270 (91.9) | 20 (8.1) | 0.559 |
| ***Hospital Setting*** | | | |
| Public | 1226 (93.8) | 120 (6.2) | |
| Private | 694 (91.1) | 46 (8.9) | 0.034 |
| ***Operating Surgeon*** | | | |
| Consultant | 1590 (92.2) | 135 (7.8) | |
| Fellow Supervised | 249 (91.5) | 23 (8.5) | |
| Fellow Unsupervised | 14 (93.3) | 1 (6.7) | |
| Registrar Supervised | 34 (81) | 8 (19.0) | 0.072 |
| ***ASA Score*** | | | |
| I | 290 (89.5) | 34 (10.5) | |
| II | 990 (93.2) | 72 (6.8) | |
| III | 556 (91.0) | 55 (9.0) | |
| IV | 36 (90.0) | 4 (10.0) | |
| V | 1 (50.0) | 1 (50.0) | 0.033 |
| ***Tumour Height*** | | | |
| 0 | 61 (93.8) | 4 (6.2) | |
| 1 | 79 (89.8) | 9 (10.2) | |
| 2 | 167 (89.8) | 19 (10.2) | |
| 3 | 225 (92.6) | 18 (7.4) | |
| 4 | 270 (94.1) | 17 (5.9) | |
| 5 | 320 (93.0) | 24 (7.0) | |
| 6 | 336 (94.6) | 19 (5.4) | |
| Unknown | 471 (89.2) | 57 (10.8) | 0.062 |
| ***Preoperative Staging*** | | | |
| ***T Stage*** | | | |
| 0 | 201 (98.5) | 3 (1.5) | |
| In situ | 11 (100.0) | 0 | |
| 1 | 259 (97.7) | 6 (2.3) | |
| 2 | 482 (97.0) | 15 (3.0) | |
| 3 | 712 (88.6) | 92 (11.4) | |
| 4 | 106 (67.5) | 51 (32.5) | |
| Unknown | 158 (100.0) | 0 | <0.001 |
| ***N Stage*** | | | |
| 0 | 1168 (95.0) | 62 (5.0) | |
| 1 | 425 (87.6) | 60 (12.4) | |
| 2 | 133 (77.8) | 38 (22.2) | |
| Unknown | 203 (96.7) | 7 (3.3) | <0.001 |

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| Variables | CRM -ve n (%) | CRM +ve n (%) | p-value |
|---|---|---|---|
| ***M Stage*** | | | |
| 0 | 1436 (93.1) | 107 (6.9) | |
| 1 | 126 (79.7) | 32 (20.3) | |
| Unknown | 367 (92.9) | 28 (7.1) | <0.001 |
| ***Neoadjuvant Therapy*** | | | |
| Yes | 1182 (90.9) | 119 (9.1) | |
| No | 665 (93.4) | 47 (6.6) | 0.051 |
| ***Operative Urgency*** | | | |
| Emergency | 7 (77.8) | 2 (22.) | |
| Urgent | 38 (84.4) | 7 (15.6) | |
| Elective | 1878 (92.3) | 157 (7.7) | 0.045 |
| ***Surgical Entry*** | | | |
| Open | 993 (89.1) | 122 (10.9) | |
| Laparoscopic | 506 (96.7) | 17 (3.3) | |
| Hybrid | 123 (91.1) | 12 (8.9) | |
| Conversion to open | 67 (94.4) | 4 (5.6) | |
| Robotic | 67 (94.4) | 4 (5.6) | |
| Transanal | 93 (93.9) | 6 (6.1) | |
| taTME | 42 (95.5) | 2 (4.5) | <0.001 |
| ***Reconstruction Method*** | | | |
| Colonic pouch | 190 (95.0) | 10 (5.0) | |
| Coloplasty | 13 (100.0) | 0 | |
| End-side anastomosis | 87 (94.6) | 5 (5.4) | |
| Straight end-end anastomosis | 269 (95.4) | 13 (4.6) | 0.854 |
| Unknown | 1370 (90.8) | 139 (9.2) | |
| ***Overall Stage*** | | | |
| 0 | 181 (98.9) | 2 (1.1) | |
| 1 | 562 (97.2) | 16 (2.8) | |
| 2 | 358 (89.1) | 44 (10.9) | |
| 3 | 440 (86.1) | 71 (13.9) | |
| 4 | 115 (78.2) | 32 (21.8) | |
| Missing | 273 (99.3) | 2 (0.7) | <0.001 |

Table 4. Predictive Ratios for APR and CRM Status

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| Independent Predictors for APR | | | | | |
|---|---|---|---|---|---|
| **Variables** | **Coefficient** | **SE** | **Odds Ratio** | **95%CI** | **p-value** |
| ***T Stage*** | | | | | <0.001 |
| 0 | | | 1.00 | | |
| In situ | -0.86 | 0.76 | 0.43 | 0.62-2.9 | |
| 1 | -6.33 | 4.87 | 0.53 | 0.3-0.93 | |
| 2 | 0.32 | 1.70 | 1.37 | 0.85-2.2 | |
| 3 | 0.39 | 3.03 | 1.48 | 0.95-2.3 | |
| 4 | 1.12 | 9.59 | 3.05 | 1.51-6.18 | |
| ***Rectal Cancer Height*** | | | | | <0.001 |
| 6 | | | 1.00 | | |
| 5 | 0.81 | 0.24 | 2.25 | 1.4-3.62 | |
| 4 | 2.29 | 0.24 | 9.84 | 6.2-15.61 | |
| 3 | 2.97 | 0.26 | 19.48 | 11.83-32.1 | |
| 2 | 3.41 | 0.29 | 30.40 | 17.4-53.13 | |
| 1 | 3.95 | 0.42 | 51.86 | 22.64-118.82 | |
| 0 | 3.37 | 0.42 | 29.12 | 12.71-66.72 | |
| ***Constant*** | -2.20 | 0.27 | | | |
| **Independent Predictors for CRM +ve** | | | | | |
| ***T Stage*** | | | | | |
| 0 | | | | | <0.001 |
| 1 | -0.66 | 1.23 | 0.52 | 0.05-5.77 | |
| 2 | 1.04 | 0.78 | 2.82 | 0.62-12.88 | |
| 3 | 1.95 | 0.73 | 7.06 | 1.69-29.55 | |
| 4 | 3.42 | 0.75 | 30.53 | 6.96-133.81 | |
| **Constant** | -4.29 | 0.71 | | | |

SE – standard error, CI – confidence interval

Cancer Rectal Height- cm from anal verge

| **Complications** | **Resection with anastomosis n (%)** | **APR n (%)** | **p-value** |
|---|---|---|---|
| **TOTAL** | n=872 | n=1224 | |
| ***Surgical Complications*** | 242 (27.8) | 515 (42.1) | <0.001 |
| ***Pelvic Collection*** | 57 (6.5) | 66 (5.4) | 0.300 |

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| | | | |
|---|---|---|---|
| ***Superficial Wound Dehiscence*** | 7 (0.8) | 103 (8.4) | <0.001 |
| ***Deep Wound Dehiscence*** | 7 (0.8) | 43 (3.5) | <0.001 |
| ***Wound Infection*** | 24 (2.8) | 126 (10.3) | <0.001 |
| ***Ileus*** | 82 (9.4) | 146 (11.9) | 0.075 |
| ***Urinary Retention*** | 35 (4.0) | 81 (6.6) | 0.011 |
| ***Post-operative haemorrhage*** | 17 (1.9) | 25 (2.0) | 1.000 |
| ***Return to Theatre*** | 71 (8.5) | 107 (9.0) | 0.750 |
| ***Medical Complications*** | 107 (12.3) | 193 (15.8) | 0.027 |
| ***Chest Infection*** | 21 (2.4) | 59 (4.8) | 0.005 |
| **Cardiac Complications** | 26 (3.0) | 51 (4.2) | 0.160 |
| ***DVT/PE*** | 4 (0.5) | 13 (1.1) | 0.146 |
| ***Inpatient Mortality*** | 9 (1.1) | 19 (1.6) | 0.440 |

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| Variables | Resection with anastomosis | APR | p-value |
|---|---|---|---|
| | n (%) | n (%) | |
| **TOTAL** | **n=872** | **n=1224** | |
| ***Sex*** | | | |
| Male | 563 (64.6) | 787 (64.3) | |
| Female | 309 (35.4) | 437 (35.7) | 0.926 |
| ***Country*** | | | |
| Australia | 648 (74.3) | 922 (75.3) | |
| New Zealand | 224 (25.7) | 302 (24.7) | 0.609 |
| ***Hospital Location*** | | | |
| Urban | 751 (86.1) | 1055 (86.2) | |
| Rural | 121 (13.9) | 169 (13.8) | 1.000 |
| ***Hospital Setting*** | | | |
| Public | 511 (59.0) | 835 (68.4) | |
| Private | 355 (41.0) | 385 (31.6) | <0.001 |
| **Operating Surgeon** | | | |
| Consultant | 737 (86.6) | 988 (82.1) | |
| Fellow Supervised | 93 (10.9) | 179 (14.9) | |
| Fellow Unsupervised | 5 (0.6) | 10 (0.8) | |
| Registrar Supervised | 16 (1.9) | 26 (2.2) | 0.054 |
| ***ASA Score*** | | | |
| I | 178 (20.8) | 146 (12.4) | |
| II | 463 (54.0) | 599 (50.7) | |
| III | 196 (22.9) | 415 (35.1) | |
| IV | 19 (2.2) | 21 (1.8) | |
| V | 1 (0.1) | 1 (0.1) | <0.001 |

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| Variables | Resection with anastomosis n (%) | APR n (%) | p-value |
|---|---|---|---|
| **TOTAL** | n=872 | n=1224 | |
| ***Preoperative Imaging Modality*** | | | |
| MRI | 692 (81.3) | 792 (81.9) | 0.762 |
| ERUS | 69 (8.1) | 30 (3.8) | <0.001 |
| CT | 299 (36.5) | 280 (36.8) | 0.917 |
| ***Tumour Height*** | | | |
| 0 | 16 (1.8) | 49 (4.0) | |
| 1 | 17 (1.9) | 71 (5.8) | |
| 2 | 44 (5.0) | 142 (11.6) | |
| 3 | 79 (9.1) | 164 (13.4) | |
| 4 | 140 (16.1) | 147 (12.0) | |
| 5 | 264 (30.3) | 80 (6.5) | |
| 6 | 312 (35.8) | 43 (3.5) | |
| Unknown | 0 | 528 (43.1) | <0.001 |
| ***Pathology*** | | | |
| ***T Stage*** | | | |
| 0 | 97 (11.1) | 107 (8.7) | |
| In situ | 8 (0.9) | 3 (0.2) | |
| 1 | 160 (18.3) | 105 (8.6) | |
| 2 | 210 (24.1) | 287 (23.4) | |
| 3 | 284 (32.6) | 520 (42.5) | |
| 4 | 33 (3.8) | 124 (10.1) | |
| Unknown | 80 (9.2) | 78 (6.4) | <0.001 |
| ***N Stage*** | | | |
| 0 | 471 (54.0) | 759 (62.0) | |
| 1 | 200 (22.9) | 285 (23.3) | |
| 2 | 65 (7.5) | 106 (8.7) | |
| Unknown | 136 (15.6) | 74 (6.0) | 0.51 |
| ***M Stage*** | | | |
| 0 | 619 (71.0) | 924 (75.5) | |
| 1 | 48 (5.5) | 110 (9.0) | |
| Unknown | 205 (23.5) | 190 (15.5) | 0.01 |
| ***Neoadjuvant Therapy*** | | | |
| Yes | 513 (60.0) | 788 (68.0) | |
| No | 342 (40.0) | 370 (32.0) | <0.001 |
| Unknown | 83(3.9%) | | |
| ***Operative Urgency*** | | | |
| Emergency | 3 (0.3) | 6 (0.5) | |
| Urgent | 26 (3.0) | 19 (1.6) | |
| Elective | 842 (96.7) | 1193 (97.9) | 0.077 |
| ***Surgical Entry*** | | | |
| Open | 350 (40.2) | 765 (64.4) | |
| Laparoscopic | 217 (24.9) | 306 (25.8) | |
| Hybrid | 86 (9.9) | 49 (4.1) | |
| Conversion to open | 34 (3.9) | 37 (3.1) | |
| Robotic | 41 (4.7) | 30 (2.5) | |

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| | | | |
|---|---|---|---|
| Transanal | 99 (11.4) | 0 | |
| taTME | 43 (4.9) | 1 (0.1) | <0.001 |

| Variables | Resection with anastomosis n (%) | APR n (%) | p-value |
|---|---|---|---|
| **TOTAL** | n=872 | n=1224 | |
| ***Reconstruction Method*** | | | |
| Colonic pouch | 200 (34.1) | 0 | |
| Coloplasty | 13 (2.2) | 0 | |
| End-side | 92 (15.7) | 0 | |
| Straight end-end anastomosis | 282 (48.0) | 0 | |
| ***Overall Stage*** | | | |
| 0 | 91 (11.7) | 92 (8.6) | |
| 1 | 291 (37.4) | 287 (26.8) | |
| 2 | 117 (15.0) | 285 (26.7) | |
| 3 | 218 (28.0) | 293 (27.4) | |
| 4 | 46 (5.9) | 101 (9.4) | |
| Missing | 15 (1.9) | 11 (1.0) | <0.001 |
| ***CRM*** | | | |
| Negative | 710 (93.8) | 862 (87.8) | |
| Positive | 47 (6.2) | 120 (12.2) | <0.001 |
| Missing | 357 (17%) | | |

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| Variables | CRM -ve n (%) | CRM +ve n (%) | p-value |
|---|---|---|---|
| ***Sex*** | | | |
| Male | 1241 (91.9) | 109 (8.1) | |
| Female | 688 (92.2) | 58 (7.8) | 0.866 |
| ***Country*** | | | |
| Australia | 1446 (92.1) | 124 (7.9) | |
| New Zealand | 483 (91.8) | 53 (8.2) | 0.853 |
| ***Hospital Location*** | | | |
| Urban | 1659 (93.1) | 147 (6.9) | |
| Rural | 270 (91.9) | 20 (8.1) | 0.559 |
| ***Hospital Setting*** | | | |
| Public | 1226 (93.8) | 120 (6.2) | |
| Private | 694 (91.1) | 46 (8.9) | 0.034 |
| ***Operating Surgeon*** | | | |
| Consultant | 1590 (92.2) | 135 (7.8) | |
| Fellow Supervised | 249 (91.5) | 23 (8.5) | |
| Fellow Unsupervised | 14 (93.3) | 1 (6.7) | |
| Registrar Supervised | 34 (81) | 8 (19.0) | 0.072 |
| ***ASA Score*** | | | |
| I | 290 (89.5) | 34 (10.5) | |
| II | 990 (93.2) | 72 (6.8) | |
| III | 556 (91.0) | 55 (9.0) | |
| IV | 36 (90.0) | 4 (10.0) | |
| V | 1 (50.0) | 1 (50.0) | 0.033 |
| ***Tumour Height*** | | | |
| 0 | 61 (93.8) | 4 (6.2) | |
| 1 | 79 (89.8) | 9 (10.2) | |
| 2 | 167 (89.8) | 19 (10.2) | |
| 3 | 225 (92.6) | 18 (7.4) | |
| 4 | 270 (94.1) | 17 (5.9) | |
| 5 | 320 (93.0) | 24 (7.0) | |
| 6 | 336 (94.6) | 19 (5.4) | |
| Unknown | 471 (89.2) | 57 (10.8) | 0.062 |
| ***Preoperative Staging*** | | | |
| ***T Stage*** | | | |
| 0 | 201 (98.5) | 3 (1.5) | |
| In situ | 11 (100.0) | 0 | |
| 1 | 259 (97.7) | 6 (2.3) | |
| 2 | 482 (97.0) | 15 (3.0) | |
| 3 | 712 (88.6) | 92 (11.4) | |
| 4 | 106 (67.5) | 51 (32.5) | |
| Unknown | 158 (100.0) | 0 | <0.001 |
| ***N Stage*** | | | |
| 0 | 1168 (95.0) | 62 (5.0) | |
| 1 | 425 (87.6) | 60 (12.4) | |
| 2 | 133 (77.8) | 38 (22.2) | |
| Unknown | 203 (96.7) | 7 (3.3) | <0.001 |

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| Variables | CRM -ve n (%) | CRM +ve n (%) | p-value |
|---|---|---|---|
| ***M Stage*** | | | |
| 0 | 1436 (93.1) | 107 (6.9) | |
| 1 | 126 (79.7) | 32 (20.3) | |
| Unknown | 367 (92.9) | 28 (7.1) | <0.001 |
| ***Neoadjuvant Therapy*** | | | |
| Yes | 1182 (90.9) | 119 (9.1) | |
| No | 665 (93.4) | 47 (6.6) | 0.051 |
| ***Operative Urgency*** | | | |
| Emergency | 7 (77.8) | 2 (22.) | |
| Urgent | 38 (84.4) | 7 (15.6) | |
| Elective | 1878 (92.3) | 157 (7.7) | 0.045 |
| ***Surgical Entry*** | | | |
| Open | 993 (89.1) | 122 (10.9) | |
| Laparoscopic | 506 (96.7) | 17 (3.3) | |
| Hybrid | 123 (91.1) | 12 (8.9) | |
| Conversion to open | 67 (94.4) | 4 (5.6) | |
| Robotic | 67 (94.4) | 4 (5.6) | |
| Transanal | 93 (93.9) | 6 (6.1) | |
| taTME | 42 (95.5) | 2 (4.5) | <0.001 |
| ***Reconstruction Method*** | | | |
| Colonic pouch | 190 (95.0) | 10 (5.0) | |
| Coloplasty | 13 (100.0) | 0 | |
| End-side anastomosis | 87 (94.6) | 5 (5.4) | |
| Straight end-end anastomosis | 269 (95.4) | 13 (4.6) | 0.854 |
| Unknown | 1370 (90.8) | 139 (9.2) | |
| ***Overall Stage*** | | | |
| 0 | 181 (98.9) | 2 (1.1) | |
| 1 | 562 (97.2) | 16 (2.8) | |
| 2 | 358 (89.1) | 44 (10.9) | |
| 3 | 440 (86.1) | 71 (13.9) | |
| 4 | 115 (78.2) | 32 (21.8) | |
| Missing | 273 (99.3) | 2 (0.7) | <0.001 |

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Table 4. Predictive Ratios for APR and CRM Status

| Independent Predictors for APR | | | | | |
|---|---|---|---|---|---|
| **Variables** | **Coefficient** | **SE** | **Odds Ratio** | **95%CI** | **p-value** |
| ***T Stage*** | | | | | <0.001 |
| 0 | | | 1.00 | | |
| In situ | -0.86 | 0.76 | 0.43 | 0.62-2.9 | |
| 1 | -6.33 | 4.87 | 0.53 | 0.3-0.93 | |
| 2 | 0.32 | 1.70 | 1.37 | 0.85-2.2 | |
| 3 | 0.39 | 3.03 | 1.48 | 0.95-2.3 | |
| 4 | 1.12 | 9.59 | 3.05 | 1.51-6.18 | |
| ***Rectal Cancer Height*** | | | | | <0.001 |
| 6 | | | 1.00 | | |
| 5 | 0.81 | 0.24 | 2.25 | 1.4-3.62 | |
| 4 | 2.29 | 0.24 | 9.84 | 6.2-15.61 | |
| 3 | 2.97 | 0.26 | 19.48 | 11.83-32.1 | |
| 2 | 3.41 | 0.29 | 30.40 | 17.4-53.13 | |
| 1 | 3.95 | 0.42 | 51.86 | 22.64-118.82 | |
| 0 | 3.37 | 0.42 | 29.12 | 12.71-66.72 | |
| ***Constant*** | -2.20 | 0.27 | | | |
| **Independent Predictors for CRM +ve** | | | | | |
| ***T Stage*** | | | | | |
| 0 | | | | | <0.001 |
| 1 | -0.66 | 1.23 | 0.52 | 0.05-5.77 | |
| 2 | 1.04 | 0.78 | 2.82 | 0.62-12.88 | |
| 3 | 1.95 | 0.73 | 7.06 | 1.69-29.55 | |
| 4 | 3.42 | 0.75 | 30.53 | 6.96-133.81 | |
| **Constant** | -4.29 | 0.71 | | | |

SE – standard error, CI – confidence interval

Cancer Rectal Height- cm from anal verge

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| Complications | Resection with anastomosis n (%) | APR n (%) | p-value |
|---|---|---|---|
| **TOTAL** | n=872 | n=1224 | |
| ***Surgical Complications*** | 242 (27.8) | 515 (42.1) | <0.001 |
| ***Pelvic Collection*** | 57 (6.5) | 66 (5.4) | 0.300 |
| ***Superficial Wound Dehiscence*** | 7 (0.8) | 103 (8.4) | <0.001 |
| ***Deep Wound Dehiscence*** | 7 (0.8) | 43 (3.5) | <0.001 |
| ***Wound Infection*** | 24 (2.8) | 126 (10.3) | <0.001 |
| ***Ileus*** | 82 (9.4) | 146 (11.9) | 0.075 |
| ***Urinary Retention*** | 35 (4.0) | 81 (6.6) | 0.011 |
| ***Post-operative haemorrhage*** | 17 (1.9) | 25 (2.0) | 1.000 |
| ***Return to Theatre*** | 71 (8.5) | 107 (9.0) | 0.750 |
| ***Medical Complications*** | 107 (12.3) | 193 (15.8) | 0.027 |
| ***Chest Infection*** | 21 (2.4) | 59 (4.8) | 0.005 |
| **Cardiac Complications** | 26 (3.0) | 51 (4.2) | 0.160 |
| ***DVT/PE*** | 4 (0.5) | 13 (1.1) | 0.146 |
| ***Inpatient Mortality*** | 9 (1.1) | 19 (1.6) | 0.440 |

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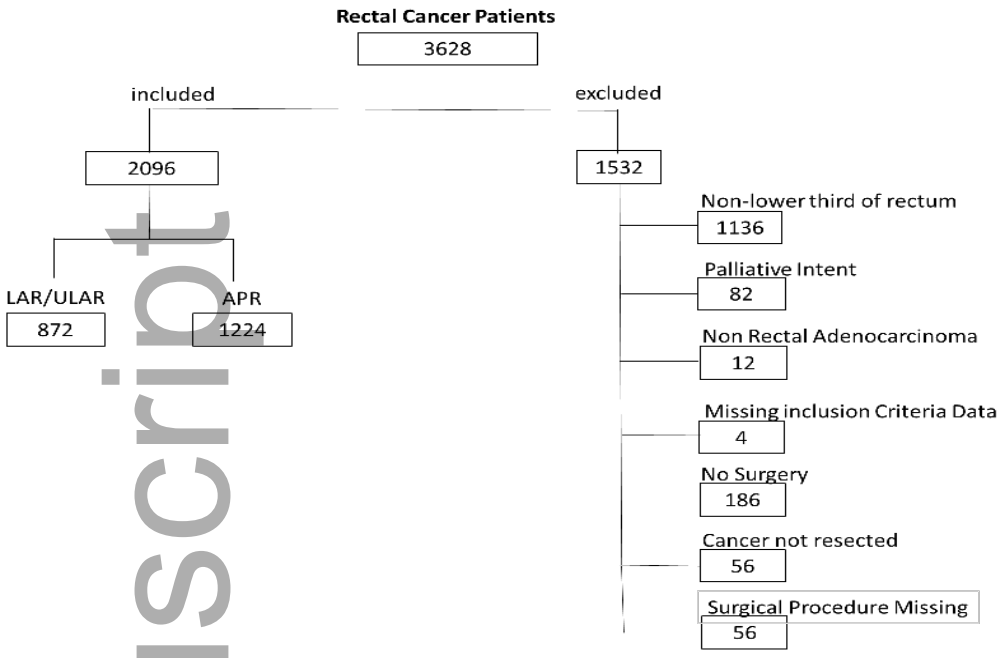


Figure 1. Included/Excluded Patient Numbers and Reasons for Study Exclusion

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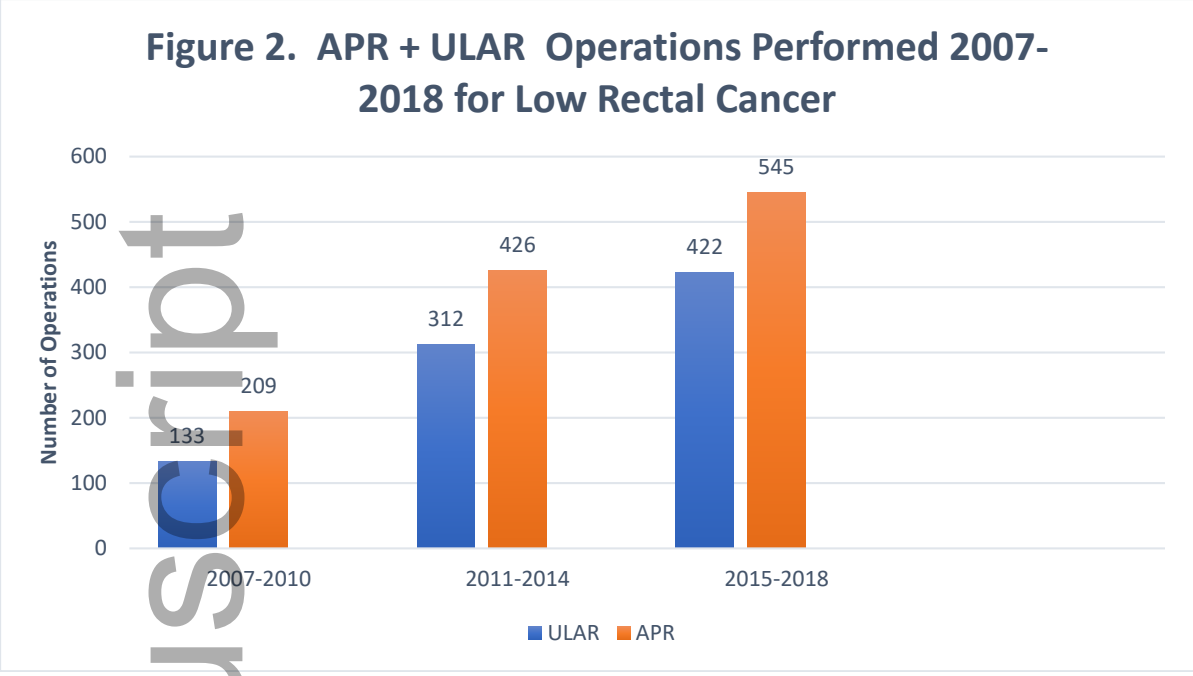


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