Incidence trends and predictors for cost and average lengths of stay in colorectal cancer surgery

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Abstract

AIM: To evaluate the changing trends and outcomes of colorectal cancer (CRC) surgery performed at a large single institution in Taiwan.

METHODS: This study retrospectively analyzed 778 patients who received colorectal cancer surgery at E-Da Hospital in Taiwan from 2004 to 2009. These patients were from health examination, inpatient or emergency settings. The following attributes were analyzed in patients who had undergone CRC surgical procedures: gender, age, source, surgical type, tumor number, tumor size, number of lymph node metastasis, pathologic differentiation, chemotherapy, distant metastases, tumor site, tumor stage, average hospitalization cost and average lengths of stay (ALOS). The odds ratio and 95% confidence intervals were calculated to assess the relative rate of change. Regression models were employed to predict average hospitalization cost and ALOS.

RESULTS: The study sample included 458 (58.87%) males and 320 (41.13%) females with a mean age of 64.53 years (standard deviation, 12.33 years; range, 28-86 years). The principal patient source came from inpatient and emergency room (96.02%). The principal tumor sites were noted at the sigmoid colon (35.73%) and rectum (30.46%). Most patients exhibited a tumor stage of 2 (37.28%) or 3 (34.19%). The number of new CRC surgeries performed per 100000 persons was 12.21 in 2004 and gradually increased to 17.89 in 2009, representing a change of 46.52%. During the same period, the average hospitalization cost and ALOS decreased from $5303 to $4062 and from 19.7 to 14.4 days, respectively. The following factors were associated with considerably decreased hospital resource utilization: age, source, surgical type, tumor size, tumor site, and tumor stage.

CONCLUSION: These results can be generalized to patient populations elsewhere in Taiwan and to other countries with similar patient profiles.

Key words: Colorectal cancer; Average hospitalization cost; Average lengths of stay; Incidence trend; Colorectal cancer surgery

Core tip: We evaluated the trend of colorectal cancer surgery and compared hospitalization cost and length of stay with those in other countries. Age, source, surgical type, tumor size, tumor site, and tumor stage were associated with decreased hospital resource utilization. To efficiently allocate of medical resources, these factors must be managed.

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INTRODUCTION

Colorectal cancer (CRC) is one of the leading causes of cancer-related death in the world. In a recent data analysis from cancer registries participating in the Surveillance, Epidemiology, and End Results program, 148,810 new cases of CRC with 49,960 deaths were estimated for the United States in 2008. In Europe, CRC was the second most common form of cancers and cause of death from cancer in 2006. By contrast, incidence rates tend to be lower in Africa and Asia, which is attributed to differences in diet and lifestyle. Moreover, the medical expenses associated with CRC cannot be ignored. The estimated medical expense for a patient with CRC in the United States of America per year is $38,577, which is seven times higher than that for a patient without CRC ($5,126).

The effectiveness of CRC surgery in relieving pain and improving physical function has been well documented. In addition to improved surgical techniques, the excellent performance of new materials and designs has substantially increased the demand for CRC surgery. The growing population of elderly patients is yet another factor. Because the system provides insurance coverage for expensive and frequently used medical items, the financial burden of CRC surgery should not be overlooked.

Although the volume of CRC surgical procedures is increasing annually, the incidence rates and hospital resource utilization for these procedures have not been documented in a Taiwan study. Thus, this study explored the changing trends and risk factors of these outcomes for CRC surgery.

MATERIALS AND METHODS

E-Da Hospital is a 1200-bed hospital, a large medical institution in Taiwan, and provides secondary and tertiary medical care for approximately one million people. A retrospective review of all patients who underwent CRC surgery from 2004 to 2009 was performed. If patients had intraoperative perforations, concurrent malignancy, or a psychological or linguistic impairment, they were excluded. All malignancies were confirmed upon histological evaluation. The study analyzed 778 CRC surgical procedures. The study protocol was approved by the Institutional Review Board of E-Da Hospital.

The following attributes were analyzed in patients who had undergone CRC surgical procedures in Taiwan: gender, age, source, surgical type, tumor number, tumor size, number of lymph node metastasis, pathologic differentiation, chemotherapy, distant metastases, tumor site, tumor stage, average hospitalization cost and average lengths of stay (ALOS). The age categories were ≤ 30, 31-40, 41-50, 51-60, 61-70, 71-80 and ≥ 81 years old. The patient source came from health examination, inpatient and emergency room settings. The surgical types were grouped as low anterior resection, high anterior resection, abdominoperineal resection, right hemicolectomy, left hemicolectomy, super low anterior resection and endoscopic polypectomy. Pathologic differentiation was classified as well, moderate or poor. The patients were grouped by tumor site as follows: ascending colon, transverse colon, descending colon, sigmoid colon and rectum. Tumor stage was categorized as 1, 2, 3 or 4. All colorectal cancers were staged according to the guidelines of the American Joint Committee of Cancer.

Continuous variables were tested for statistical significance by one-way analysis of variance (ANOVA), and categorical variables were tested by the χ² analysis. Temporal trends were assessed by the Cochrane-Armitage trend test. The study period was divided into three equal time intervals (P1: 2004-2005; P2: 2006-2007; and P3: 2008-2009). The odds ratio and 95% confidence interval were determined to assess the relative change for each factor when using P1 as the reference group when compared to P3. We define the incidence rate as the number of new cases of colorectal cancer surgery from health examination, inpatient or emergency room divided by the total number of cases from those settings.

Regarding treatment costs, the standard administrative claims data required by the Bureau of National Health Insurance (BNHI) included the following fees: operating room, radiology, physical therapy, hospital room, anesthetist, pharmacy, laboratory, special materials, surgeon, and others. To reflect changes in real dollar value, the cost data were adjusted by the consumer price index for each year from 2004-2009 (93.70, 95.86, 96.43, 98.17, 101.63 and 100.00). The hospital treatment costs were then converted from Taiwan dollars to United States dollars at an exchange rate of 31.5:1, which was the average exchange rate during 2004-2009. The hospital treatment costs at different hospital levels were also adjusted for differences in BNHI reimbursements. The multiple regression models used to predict average hospitalization cost and ALOS included both patient and clinical attributes.

Statistical analysis

Statistical analyses were performed using SPSS version 15.0 (SPSS Inc., Chicago, IL, United States). All of the tests were two-sided, and P values less than 0.05 were considered statistically significant.

RESULTS

The study sample included 458 (58.87%) males and 320 (41.13%) females with a mean age of 64.53 years (standard deviation, 12.33 years; range, 28-86 years). The principal patient source came from inpatient and emergency rooms (96.02%). The principal surgical types for the study population were low anterior resection, right hemicolectomy, super low anterior resection, left hemicolectomy, high anterior resection, abdominoperineal resection, and endoscopic polypectomy at the following frequencies: 25.32%, 23.78%, 17.74%, 12.20%, 10.54%, 6.56%, and 3.86%,
respectively. On average, the number of tumors, size of the tumor, and number of lymph node metastases were (mean ± SD) 1.05 ± 0.29, 5.06 ± 2.14, and 3.56 ± 5.15, respectively. Pathologic differentiation included the following classifications: moderate (82.01%), well (11.05%), and poor (6.94%). In the study, 52.70% cases received chemotherapy after colorectal cancer surgery, and distant metastases were not found in 93.44% cases when these patients were included in the study. The principal tumor site was described in the sigmoid colon (35.73%) and rectum (30.46%). Most patients exhibited a tumor stage of 2 (37.28%) or 3 (34.19%). Additionally, the average treatment costs were US$4285 ± 2845.4, and the ALOS was 15.40 ± 8.12 d. The detailed patient characteristics are shown in Table 1.

The incidence rate of CRC surgery in 2004 was 12.21 per 100000 persons, and the rate gradually increased to 17.89 in 2009, which represented a change of 46.52% (Table 2). A significant decreased trends analysis was also observed in average hospitalization cost and ALOS in CRC surgery patients during the study period (P < 0.01) (Figure 1).

Table 3 shows the increasing volume of CRC surgical procedures and the changes in patient demographic and clinical characteristics. Approximately 40% of all CRC surgery patients treated from P1 to P3 were female, and the number of female patients significantly increased between P1 and P3 (OR = 1.13, 95%CI: 1.01-1.25). Conversely, the number of male patients significantly decreased. The number of CRC surgery patients younger than 30 years old significantly decreased between P1 and P3 (OR = 0.46, 95%CI: 0.33-0.60). The number of CRC surgery patients aged 51 to 60 years old significantly increased from P1 to P3 (OR = 1.78, 95%CI: 1.58-1.97) but the number of CRC surgery patients aged 61 to 70 years old significantly decreased (OR = 0.71, 95%CI: 0.56-0.87). The number of CRC surgery patients older than 81 years old significantly increased between P1 and P3 (OR = 1.22, 95%CI: 1.06-1.37). The number of CRC surgery patients from health examinations significantly increased (OR = 5.78, 95%CI: 5.48-6.08). In terms of surgical type, the data revealed a statistically significant decrease in the number of patients with low anterior resection and super low anterior resection between P1 and P3 (OR = 0.02, 95%CI: 0.00-0.04 and OR =

Table 1  Patient characteristics (n = 778)

| Variable                                | n (% ) |
|-----------------------------------------|--------|
| Gender                                  |        |
| Female                                  | 320 (41.13) |
| Male                                    | 458 (58.87) |
| Age (yr)                                | 64.53 ± 12.33 |
| ≤ 30                                    | 9 (1.16)  |
| 31-40                                   | 23 (2.96)  |
| 41-50                                   | 62 (7.97)  |
| 51-60                                   | 187 (24.04) |
| 61-70                                   | 218 (28.02) |
| 71-80                                   | 219 (28.15) |
| ≥ 81                                    | 60 (7.71)  |
| Source                                  |        |
| Health examination                      | 31 (3.98) |
| Inpatient or emergency room              | 747 (96.02) |
| Surgical type                           |        |
| Low anterior resection                   | 197 (25.32) |
| High anterior resection                  | 82 (10.54) |
| Abdominoperineal resection               | 51 (6.56)  |
| Right hemicolectomy                      | 185 (23.78) |
| Left hemicolectomy                       | 95 (12.2)  |
| Super low anterior resection             | 138 (17.74) |
| Endoscopic polypectomy                   | 30 (3.86)  |
| Tumor number                            | 1.05 ± 0.29 |
| Tumor size                              | 5.06 ± 2.14 |
| No. of lymph node metastases            | 3.56 ± 5.15 |
| Pathologic differentiation              |        |
| Well                                    | 86 (11.05) |
| Moderate                                | 636 (82.01) |
| Poor                                    | 54 (6.94)  |
| Chemotherapy                            |        |
| No                                      | 368 (47.30) |
| Yes                                     | 410 (52.70) |
| Distant metastasis                      |        |
| No                                      | 727 (93.44) |
| Yes                                     | 51 (6.56)  |
| Tumor site                              |        |
| Ascending colon                         | 145 (18.64) |
| Transverse colon                        | 67 (8.61)  |
| Descending colon                        | 51 (6.56)  |
| Sigmoid colon                           | 278 (35.73) |
| Rectum                                  | 237 (30.46) |
| Tumor stage                             |        |
| 1                                       | 144 (18.51) |
| 2                                       | 290 (37.28) |
| 3                                       | 266 (34.19) |
| 4                                       | 78 (10.03)  |
| Treatment cost (dollars)                | 128543.94 ± 85360.59 |
| Average length of stay (d)              | 15.40 ± 8.12 |

Table 2  The incidence rate of colorectal cancer surgery

| Year | Patients (n) | Surgeries (n) | Incidence rate (1/10⁵) |
|------|--------------|--------------|-----------------------|
| 2004 | 245734       | 30           | 12.21                 |
| 2005 | 621243       | 99           | 15.94                 |
| 2006 | 727286       | 158          | 21.72                 |
| 2007 | 782659       | 136          | 17.38                 |
| 2008 | 825907       | 199          | 24.09                 |
| 2009 | 877791       | 157          | 17.89                 |

Figure 1  The trend analyses of average hospitalization cost and average lengths of stay in colorectal cancer surgery patients during the study period.
0.57, 95%CI: 0.38-0.76, respectively) but a statistically significant increase in the number of patients with high anterior resection, abdominoperineal resection and right hemicolectomy between P1 and P3 (OR = 5.49, 95%CI: 5.19-5.82; OR = 3.76, 95%CI: 3.54-3.99; and OR = 1.16, 95%CI: 1.00-1.36, respectively). The number of CRC surgery patients who exhibited well-differentiated tumors significantly decreased (OR = 0.75, 95%CI: 0.51-0.92). The number of CRC surgery patients without distant metastases significantly increased from P1 to P3 (OR = 1.16, 95%CI: 1.05-1.31) while the number of CRC surgery patients with tumors at the rectum significantly decreased (OR = 0.20, 95%CI: 0.02-0.40). The number of CRC surgery patients with tumors at the sigmoid colon significantly increased from P1 to P3 (OR = 1.75, 95%CI: 1.43-2.23) while the number of CRC surgery patients with tumors at the rectum significantly decreased (OR = 0.64, 95%CI: 0.42-0.93). The number of CRC surgery patients with stage 1 tumors significantly increased from P1 to P3 (OR = 1.16, 95%CI: 1.00-1.36) while the number of CRC surgery patients with stage 2 tumors significantly decreased (OR = 0.64, 95%CI: 0.42-0.93). The number of CRC surgery patients with stage 3 tumors significantly decreased (OR = 0.20, 95%CI: 0.02-0.40) but a statistically significant increase in the number of patients with high anterior resection, abdominoperineal resection and right hemicolectomy between P1 and P3 (OR = 5.49, 95%CI: 5.19-5.82; OR = 3.76, 95%CI: 3.54-3.99; and OR = 1.16, 95%CI: 1.00-1.36, respectively). The number of CRC surgery patients who exhibited well-differentiated tumors significantly decreased (OR = 0.75, 95%CI: 0.51-0.92). The number of CRC surgery patients without distant metastases significantly increased from P1 to P3 (OR = 1.16, 95%CI: 1.05-1.31) while the number of CRC surgery patients with tumors at the rectum significantly decreased (OR = 0.20, 95%CI: 0.02-0.40).

### DISCUSSION

This large survey study is the first to examine how patient and clinical attributes reflect changing trends in the incidence of CRC surgery and the first to identify factors that predict average hospitalization costs and ALOS for the procedure. This study showed a gradual increase in the incidence of new CRC surgeries during the study period and, during the same period, a demographic decrease in hospital resource utilization, which is consistent with other series studies. The following factors were associated with the considerably decreased hospital resource utilization of CRC surgery: age, source, surgical type, tumor size, tumor site, distant metastasis, and tumor stage.

Old age is a risk factor for the occurrence of CRC\(^2,11,12\). However, according to the results of this study, we found a trend of increasing incidence of CRC in patients aged 51-60 years old from the first to third time period. In the first time period, the percentage of 51-60 years old patients with CRC is only 16.10%, but this incidence increases to 20.88% and 28.68% in the second and third

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**Table 3** Logistic regression model for colorectal cancer surgery during periods 1-3\(^1\)

| Variables                      | P1 (n = 118) | P2 (n = 273) | P3 (n = 387) | OR (95%CI) |
|-------------------------------|-------------|-------------|-------------|------------|
| Gender                        | Female      | 35.99       | 44.69       | 40.31      | 1.13 (1.01-1.25) |
|                               | Male        | 64.41       | 55.31       | 59.69      | 0.93 (0.83-1.06) |
| Age (yr)                      | ≤ 30        | 1.69        | 1.47        | 0.78       | 0.46 (0.33-0.60) |
|                               | 31-40       | 2.54        | 3.30        | 2.84       | 1.12 (0.96-1.28) |
|                               | 41-50       | 5.93        | 10.62       | 6.72       | 1.13 (0.99-1.27) |
|                               | 51-60       | 16.10       | 20.88       | 28.68      | 1.78 (1.58-1.97) |
|                               | 61-70       | 35.59       | 28.94       | 25.06      | 0.71 (0.56-0.87) |
|                               | ≥ 81        | 31.36       | 27.47       | 27.65      | 0.88 (0.73-1.03) |
| Source                        | Health examination | 0.85 | 4.05 | 4.91 | 5.78 (5.48-6.08) |
|                               | Inpatient or emergency room | 99.15 | 95.97 | 95.09 | 0.96 (0.74-1.18) |
| Surgical type                 | Low anterior resection | 35.59 | 25.64 | 0.62 | 0.02 (0.00-0.04) |
|                               | High anterior resection | 3.39 | 2.2 | 18.60 | 5.49 (5.19-5.82) |
|                               | Abdominoperineal resection | 2.54 | 4.03 | 9.56 | 3.76 (3.54-3.99) |
|                               | Right hemicolectomy | 20.34 | 25.64 | 23.51 | 1.16 (1.00-1.36) |
|                               | Left hemicolectomy | 14.41 | 12.09 | 11.63 | 0.81 (0.61-1.05) |
|                               | Super low anterior resection | 21.19 | 24.18 | 12.14 | 0.57 (0.38-0.76) |
| Pathologic differentiation    | Well        | 14.41       | 9.89        | 10.85      | 0.75 (0.51-0.92) |
|                               | Moderate    | 77.97       | 82.78       | 82.69      | 1.06 (0.82-1.27) |
|                               | Poor        | 7.63        | 7.33        | 6.46       | 0.85 (0.59-1.05) |
| Chemotherapy                  | No          | 52.54       | 38.1        | 52.20      | 0.99 (0.70-1.47) |
|                               | Yes         | 47.46       | 61.9        | 47.80      | 1.01 (0.80-1.28) |
| Distant metastasis            | No          | 83.05       | 93.41       | 96.64      | 1.16 (1.05-1.31) |
|                               | Yes         | 16.95       | 6.59        | 3.36       | 0.20 (0.02-0.40) |
| Tumor site                    | Ascending colon | 18.64 | 19.05 | 18.35 | 0.98 (0.75-1.19) |
|                               | Transverse colon | 10.17 | 7.69 | 8.79 | 0.86 (0.70-1.06) |
|                               | Descending colon | 6.78 | 6.96 | 6.20 | 0.91 (0.79-1.14) |
|                               | Sigmoid colon | 22.88       | 35.16       | 40.05      | 1.75 (1.42-2.23) |
|                               | Rectum      | 41.53       | 31.14       | 26.61      | 0.64 (0.42-0.93) |
| Tumor stage                   | 1           | 15.25       | 16.12       | 21.19      | 1.39 (1.22-1.74) |
|                               | 2           | 38.98       | 35.16       | 38.24      | 0.98 (0.78-1.19) |
|                               | 3           | 38.98       | 32.60       | 33.85      | 0.87 (0.56-1.14) |
|                               | 4           | 6.78        | 6.12        | 6.72       | 0.99 (0.80-1.29) |

\(^1\)Period 3 (P3) vs period 1 (P1) (reference group). P1: 2004-2005; P2: 2006-2007; P3: 2008-2009.
Table 4  Impact factors for predicting the average hospitalization cost and average lengths of stay for colorectal cancer surgery

| Variables                        | Average hospitalization cost  | Average lengths of stay  |
|----------------------------------|-------------------------------|--------------------------|
|                                  | Coefficient       Standard coefficient | P value | Coefficient | Standard coefficient | P value |
| Gender                           | Female             0.01 | 0.02 | 0.344 | 0.02 | 0.05 | 0.140 |
| Age                              | -0.17              0.08 | <0.001 | 0.01 | 0.10 | 0.010 |
| Source                           | Inpatient or emergency room | -0.11 | <0.001 | 0.10 | 0.10 | 0.010 |
| Surgical type                    | High anterior resection  | -0.03 | -0.03 | 0.168 | -0.06 | -0.11 | 0.009 |
| Abdominoperineal resection       | 0.03               0.03 | 0.213 | 0.05 | 0.07 | 0.090 |
| Right hemicolectomy              | -0.01              -0.01 | 0.891 | 0.01 | 0.02 | 0.816 |
| Left hemicolectomy               | -0.01              0.01 | 0.625 | -0.01 | -0.02 | 0.707 |
| Super low anterior resection     | 0.02               0.02 | 0.478 | 0.01 | 0.02 | 0.687 |
| Endoscopic polypectomy           | -1.16              -0.75 | <0.001 | -0.69 | -0.14 | <0.001 |
| Tumor number                     | 0.05               0.03 | 0.110 | -0.01 | -0.01 | 0.805 |
| Tumor size                       | 0.01               0.06 | 0.010 | 0.01 | 0.07 | 0.062 |
| No. of lymph node metastases     | 0.01               -0.01 | 0.568 | 0.01 | 0.01 | 0.997 |
| Pathologic differentiation       | Moderate           0.04 | 0.05 | 0.104 | 0.04 | 0.07 | 0.126 |
|                                  | Poor              0.05 | 0.04 | 0.139 | 0.04 | 0.05 | 0.289 |
| Chemotherapy                     | Yes               -0.01 | 0.02 | 0.345 | -0.02 | -0.05 | 0.239 |
| Distant metastasis               | Yes               0.03 | 0.01 | 0.903 | 0.04 | 0.06 | 0.117 |
| Tumor site                       | Transverse colon   | 0.03 | 0.01 | 0.726 | 0.09 | 0.14 | 0.003 |
|                                  | Descending colon  | 0.02 | 0.02 | 0.557 | 0.04 | 0.06 | 0.287 |
|                                  | Sigmoid colon     | 0.01 | 0.02 | 0.730 | 0.06 | 0.15 | 0.149 |
|                                  | Rectum            | 0.03 | 0.04 | 0.514 | 0.04 | 0.11 | 0.314 |
| Tumor stage                      | 2                 0.04 | 0.06 | 0.076 | 0.03 | 0.07 | 0.198 |
|                                  | 3                 0.05 | 0.08 | 0.019 | 0.03 | 0.08 | 0.177 |
|                                  | 4                 0.17 | 0.17 | <0.001 | 0.09 | 0.15 | 0.002 |

1 Reference groups: gender (male), source (health examination), surgical type (low anterior resection), pathologic differentiation (well), chemotherapy (no), distant metastasis (no), tumor site (ascending colon), tumor stage (1); $R^2 = 0.68$ and adjusted $R^2 = 0.67$; $R^2 = 0.42$ and adjusted $R^2 = 0.39$. The increasing incidence of CRC is obvious and substantial in early old age from 51-60 years of age. From the first to third time period, the other difference is the increased rate of CRC cases from health examinations. In the first time period, the percentage of CRC cases from health examinations is less then 1%, but this incidence increases to nearly 5% in the third time period. We also noted that the percentage of state 1 tumor cases decreases from the first to third time period. The incidence of colorectal cancer from 2004 to 2009 is between 12.21 per 100000 per year and 24.09 per 100000 per year in this study. In another study, the median unadjusted incidence of colorectal cancer from 1989 to 2008 was 6.17 per 100000 per year in South Asians compared with 71.70 per 100000 per year in non-South Asians (77.79% white British) [13]. A previous study showed that colorectal cancer that originates from a different site may provide additional prognostic information [21]. In our study, the trend analysis showed an increasing percentage of sigmoid colon cancer, from 22.88% at time period 1 to 40.05% at time period 3, and the multiple regression model showed that tumors at transverse colon were a significant factor leading to increased ALOS. According to the result of this study, we note that CRC patients with or without distal metastases have no statistically significant difference between the average hospitalization cost and ALOS. An increasing tumor size elevates the average hospitalization cost but does not significantly affect ALOS. These findings may be due to the limited case numbers, which affected our ability to demonstrate the effect of distal metastases and tumor size on ALOS for CRC patients. A study in Brazil showed the increasing hospital admission rates and economic burden for colorectal cancer from 1996 to 2008 [22]. Our results reveal an approximate four times greater average hospital cost for patients who received colorectal cancer surgery in Taiwan compared to Brazil, but the average hospitalization costs and lengths of stay decrease each year in Taiwan. The median length of stay was 14 d for elective admissions in Ireland from 2002 to 2008 [19]. Our study shows a similar length of stay...
of 15.40 d. Compared to the conditions in the United States and Europe (between March and November 2003 in the United Kingdom, France, Germany, Italy, and Spain, and between September 2003 and October 2004 in the United States), the ALOS for a colonic operation is shortest in the United States at 7.8 d, while the ALOS for a colonic operation in countries in Europe, including France, Italy, United Kingdom, Spain and Germany, is 12.8-16.5 d\(^{[26]}\). The ALOS is similar between Taiwan and Europe. In Taiwan, the pre-operative preparation, such as radiology examination, biochemical laboratory examination, electrocardiogram and colon preparation, are arranged and performed after admission, so the average length of stay is longer in Taiwan than in the United States. Another reason that may contribute to the longer average length of stay in Taiwan is the health insurance. Public citizens in Taiwan have well-care health insurance, and they also have a higher frequency of out-patient department visits and a longer average length of stay. Furthermore, we used the regression model to observe trends and effective predictors for the average hospitalization costs and ALOS in patients who received colorectal cancer surgery.

The average hospitalization cost and ALOS decrease each year in the study. This finding may be related to the increase in stage 1 CRC that was found in a younger group of patients (51-60 years old) by general screening using a stool occult blood test and a colonoscopy at a health examination. Compared to patients with stage 4 CRC, the patients with stage 1 CRC not only have a decreased average hospitalization cost but also ALOS. The study indirectly show the benefit of the general screening using a stool occult blood test for the older patients and the value of colonoscopy at health examinations. However, the effectiveness of colonoscopy is diminished by operator-dependent factors. Therefore, quality assurance programs should be implemented in all colonoscopy practices\(^{[23]}\).

Our results should be interpreted in the context of certain limitations. For example, the existing data set used for the study contained only 6 years of data from one institution. Thus, it is possible that some of the patients in our analysis who apparently did not undergo CRC surgery had, in fact, received CRC surgery in the 6 years prior to the study’s time frame. Second, our analysis was not able to capture data on tests performed outside of the study hospital if they were not paid for by the study hospital. This limitation may have resulted in an underestimate of the adequacy of average hospitalization cost. Another potential limitation of our analysis is its dependence on claims data and the lack of data for readmission. A different study previously showed that enhanced recovery after surgery protocols may decrease the length of stay in a hospital. However, that study also noted that a reduced length of stay at a hospital was associated with a high rate of readmission\(^{[23]}\). Finally, the analysis did not examine outcome data such as patient-reported quality of life and indirect costs incurred after discharge. However, given the robust magnitude of the effects and the statistical significance of the effects in this study, these limitations are unlikely to compromise the results.

In conclusion, this analysis of CRC data from a large scale survey in Taiwan evaluated changing trends and risk factors of hospital resource utilization. The data improves the understanding of medical resource allocation for CRC surgery and may help to formulate public health policies for optimizing hospital resource utilization for related diseases. Government officials and health care providers should recognize that hospital resource utilization of CRC surgery may depend on both patient and clinical attributes. These results can be generalized to CRC surgery patient populations elsewhere in Taiwan and to similar populations in other countries.

**COMMENTS**

**Background**

Colorectal cancer (CRC) is one of the leading causes of cancer-related death in the world. Although the volume of CRC surgical procedures is increasing annually, the incidence and hospital resource utilization for these procedures have not been documented in a Taiwan study. Thus, this study explored the changing trends and risk factors of these outcomes for CRC surgery.

**Research frontiers**

These results can be generalized to patient populations elsewhere in Taiwan and to other countries with similar patient profiles.

**Innovations and breakthroughs**

This is a large retrospective study focused on the relationship between hospital costs, hospital stay and patients characteristics. It is beneficial to analyze changes in these factors over time.

**Applications**

To efficiently allocate of medical resources, these factors must be carefully managed. Moreover, government officials and health care providers should understand that these outcomes depend on both patient and hospital attributes.

**Peer review**

This research is a large sample, retrospective study and presents an interesting investigation of trend analysis and predictors for costs and hospital stay lengths after CRC surgery in the Taiwan region. The results showed that age, source, surgical type, tumor size, tumor site, and tumor stage were associated with decreased hospital resource utilization, and these findings may help to formulate public health policies in optimizing hospital resource utilization.

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