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Title Page

Complete Title: A health economic analysis of curative-intent gastrectomy for gastric carcinoma and the costs related to post-operative complications

Running Title: Gastrectomy cost analysis

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A health economic analysis of curative-intent gastrectomy for gastric carcinoma and the costs related to post-operative complications

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ABSTRACT

Background: The management of post-gastrectomy complications requires considerable resources and is likely associated with a substantial economic burden. The objectives of this study were to perform a cost-analysis of admissions following gastrectomy for gastric carcinoma and then to quantify the financial impact of post-operative complications.

Methods: A retrospective analysis was conducted in patients that underwent a gastrectomy from 2008 to 2019. Demographic data, operative information, post-operative complications and facility costs were compared.

Results: 74 patients underwent a curative-intent gastrectomy during the study period. The 36 (48.6%) patients that had no complications had a median total admission cost of AUD $29,228. 21 (28.4%) patients had a minor complication and 17 (23.0%) patients had a major complication, with a median total admission cost of AUD $36,592 and AUD$71,808, respectively. The difference across all three groups was statistically significant. In patients who had major complications compared to those without complications, there was a significant increase in the cost of intensive care services, theatre resources and nursing care. Across the whole cohort, the principal cost centres accounting for the largest proportion of total cost were theatre equipment and resources (33.9%), nursing care on the ward (23.0%) and staffing time of the surgical team (16.7%).

Conclusion: The surgical management of gastric cancer carries a substantial cost burden. The presence and severity of post-operative complications is strongly associated with increasing cost. Minimising complications, in addition to obvious clinical benefits, enables a large reduction in costs of care.

Key words: Cost, Gastrectomy, Complications, Economics, Cancer

INTRODUCTION

Gastric cancer is the fifth most common malignancy globally, and the third leading cause of cancer-related death (1). Although multimodality therapy is typically used in the management of gastric cancer, surgical resection remains the cornerstone of curative treatment (2, 3).

Survival following a gastrectomy procedure has improved with the advancement of technology and peri-operative care, however, the reported complication rate remains high, ranging from 9 to 46% (4).

Investigations of outcomes in cancer care have typically focused on morbidity, mortality and quality of life following surgery. Although patient outcomes are paramount, increasing attention is directed to the cost of treatments as this informs decisions regarding the allocation of resources.

There is a paucity of data on the economic value of gastric cancer resections as well as the components of hospital care that determine higher costs. Post-operative complications across other surgical disciplines have been found to correlate strongly with increased costs (5-8). Increased efforts to understand the clinical and economic issues associated with gastrectomy as well as the effect of post-gastrectomy complications may assist in the development of initiatives to achieve a higher value of care.

The primary objective of this study was to quantify the cost of gastrectomy and the economic burden of complications following curative-intent resection of gastric carcinoma at our institution. The secondary objective was to identify and compare the key factors that contribute to this economic burden. Through evaluation of these indicators of increased cost, the aim was to identify the relevant saving capacity of hospital admissions.

METHODS

Patient population: All patients with gastric carcinoma who underwent a gastrectomy at St Vincent's Hospital Melbourne from March 2008 to January 2019 were retrospectively identified through a review of procedure codes from the International Classification of Diseases Tenth Revision, Clinical Modifications (ICD-10-CM). Gastrectomy procedures included in this study comprised both partial and total resections. The decision to use a particular surgical approach was at the discretion of the treating surgeon. All patients had histologically verified gastric carcinoma that was deemed resectable by the treating surgeon.

Data source: Collected data included patient demographics, comorbidities, operative details, post-operative clinical outcomes including complications and length of stay and admission costing data. Medical records of all patients were manually reviewed by two researchers to ensure that all relevant data was captured.

Outcome measures: Complications were recorded based on the Clavien-Dindo classification, with minor complications defined as grade I to II, and major complications defined as Grade III to V (9, 10). In the event of multiple complications, patients were categorised based on their most severe complication. Given the substantial clinical impact of anastomotic leaks, these were investigated independently. Anastomotic leak was defined as a dehiscence of the oesophagojejunal or gastrojejunal surgical anastomosis site (11). Length of stay in this cohort was calculated as the number of days from the date of operation to the date of discharge. Admission cost data was collected from the institution's data analysis team and was determined for the duration of the inpatient admission relevant to the index gastrectomy. This was calculated from an activity-based method, where cost is determined based on the volume of a service used per patient. As demonstrated in Table 1, costs for the patient's admission

were categorised into one of twelve areas of healthcare expenditure, termed costing buckets – allied health, coronary care unit (CCU), emergency, endoscopy, intensive care unit (ICU), nursing, operating theatre, pathology, pharmacy, radiology, surgical operative care and surgical ward care. All costs are based on the 2019 Australia dollar (AUD).

Ethics: This cohort study was approved by the Human Research Ethics Committee of St Vincent's Hospital Melbourne (LNR HREC Reference: HRE/16/SVHM/127).

Statistical methods: Hospital costs were described as median and interquartile ranges (IQR), in addition to mean values and standard deviations. Categorical variables were described as number of events occurring and as a percentage of the cohort (%). Univariate analyses were conducted using Kruskal-Wallis test. Differences in cost between patients grouped by complication number or severity were determined with the one-way analysis of variance test. A p-value of <0.05 was considered statistically significant. GraphPad Prism 5, version 5.0a and IBM SPSS Statistics, version 26.0 were used for analyses.

RESULTS

Between 2008 and 2019, 74 patients underwent a resection for gastric carcinoma. Baseline demographics and operative characteristics are shown in Table 2.

Median and mean costing data for all patients is presented in Table 3, with each costing bucket shown as a proportion of total admission cost. The incidence of major complications was 23.0% and minor complications was 28.4%. There were no cases of inpatient mortality. The median hospital cost for a single patient admission for a gastrectomy procedure was

$36,438, and IQR was $26,171–53,060. The data is very positively skewed in several costing centres – CCU, Emergency, Endoscopy and ICU – as demonstrated by the variable mean cost values in spite of a median cost of $0.

As demonstrated in Table 4, the total hospital cost for each patient's admission increased with the severity of complications. The median cost per patient for those that had a major complication, $71,808, was almost double that of those that had a minor complication, $36,592, and both were significantly higher than those that had no complications, $29,228. Statistically significant changes were demonstrated in several costing buckets including allied health, ICU, nursing, pathology, pharmacy, radiology, surgical ward care and theatre. The cost centre that contributed most to this increased cost was ICU.

Figure 1 presents the median cost data of patients that were complicated by an anastomotic leak (n=4). All 4 anastomotic leaks were identified with a computed tomography scan performed in the setting of some clinical deterioration. The median admission cost for each patient with this complication was $64,105 (IQR $55,997–72,636), greater than the median cost for patients that were not complicated by an anastomotic leak, $34,981 (IQR $25,820–50,403).

DISCUSSION

The surgical management of gastric cancer is complex and has a relatively high morbidity (12). This comprehensive cost analysis at a single centre evaluates the cost of surgical admission and the influence of complication severity following curative-intent gastrectomy.

This analysis found that the major contributors to inpatient cost based on mean values included operating theatre (33.9%), nursing (23.0%) and surgical operative care (16.7%). As demonstrated in table 4, the total admission cost and specific cost centre expenses increased with the severity of complications. The combined major and minor complication rate of our cohort was 51.4%. Activity-based costing for the total admission increased from $29,228 for uncomplicated admissions, to $71,808 for those with major complications; an increase of almost 150%.

Health economics has previously been assessed in only one other gastrectomy series in which costs were also stratified by post-operative morbidity (13). In a retrospective analysis of 120 patients that underwent curative-intent total gastrectomy at a major cancer centre, Selby et al. reported similar findings with the cost of patient care significantly and substantially increasing with the severity of complications. When converted into the current Australia dollar exchange rate, initial admission costs were comparable, although marginally lower than our cohort, for patients with no complications ($18,743), minor complications ($24,534) and major complications ($62,369).

Our findings have implications for efforts to improve the cost-effectiveness of the management of gastric cancer. The marked cost implications of major complications including anastomotic leaks compared with uncomplicated admissions further emphasises the need to implement strategies to reduce adverse events. Existing potential evidence based options include directing resources towards multi-disciplinary work-up and optimisation in the pre-operative setting (14, 15), evidenced-based prehabilitation programs (16, 17), and the

centralisation of gastric cancer surgical services all of which have been found to improve outcomes (18-20).

While minor complications are perceived as clinically less significant in the overall assessment of the quality of care, this study demonstrates that these too are responsible for at least an additional $7,000 during inpatient care and occur commonly after surgery. These costs are primarily due to the increased demand on nursing care, which reflects the prolonged length of stay on the ward by a further 5 days in this study. Smaller increases in this cost are also attributable to resource consumption from pathology, pharmacy and radiology. There may be opportunities for cost containment through the rational prescribing of medication and judicious approach to ordering investigations.

Given the marked influence of length of stay on the overall cost of care there is an economic benefit in reducing the duration of admission. This may be possible through utilisation of hospital-in-the-home services, or from accelerating post-operative recovery with methods such as an Enhanced Recovery After Surgery (ERAS) program. While ERAS is aimed at reducing the physiological response to major surgery and enabling an earlier return to function, studies have demonstrated that its implementation is linked with a significantly reduced length of stay following both open and laparoscopic gastrectomy (21-23). This perioperative care pathway aims to decrease unnecessary hospital stay and could subsequently minimise cost.

When comparing complicated and uncomplicated patients, ICU was the principal driver of higher cost with a ten-fold increase in cost for those patients with major complications. While

intensive care is an integral component of modern healthcare relying on advanced technology and highly skilled specialists, a recent review determined that the cost of an ICU bed in Australia has rapidly risen over years and is currently expensed at $4,028 per day (24). This highlights the importance of adopting suitable alternatives for patients without an ICU-specific requirement. This may include using services such as a high-dependency step down unit, which is a cheaper alternative to the cost of an ICU bed, but still ensures the timely detection and prevention of complications.

The rate of bed occupancy is an important metric for planning hospital care and as a result, the value of patient bed days is an essential cost component. This study found that the economic value of bed days is not fixed, but rather, varies depending on the interventions involved, the type of complications that may occur, and a number of other factors. Prolonged length of stay was linked with an exponential increase in costs due to the complexity of care required for patients that have longer admissions as a result of morbidity. This has important implications for budgeting and with respect to modelling of the expected costs during an inpatient's stay.

Our study has several limitations to consider. Observational bias is a potential drawback of any retrospective study as this may have influenced the data collection process through under-reporting of complications. Any human error on this part, however, is reduced given the systematic recording of complications based on the Clavien-Dindo classification. The study was completed at a single institution and this limits the ability to generalise our results to other centres. Potential confounding factors that were not mentioned in the present study but have previously been found to affect hospital costs include the comparison between

laparoscopic and open approaches to surgery (25-27) and the impact of the surgeon's operating experience (28). Other inherent confounders that are difficult to quantify include the changes in perioperative care of patients that have taken place over the decade-long study period. This includes factors such as the shift towards minimally invasive surgery, the fitness of patients awaiting surgery due to the change in role of neoadjuvant systematic therapy, as well as the overall improvement in surgical management of gastric cancer.

The management of gastric cancer is becoming increasingly complex with much of the patient's management occurring in the weeks prior to surgery in the form of neoadjuvant treatment as well as staging procedures, and post-operatively with ongoing post-discharge surveillance (29, 30). The present study focused specifically on the inpatient cost for admissions relating to gastric resection and did not cover other facets of the patient's journey from diagnosis to outpatient follow-up. As a result, complications that occurred later during the patient's recovery requiring a subsequent readmission and additional costs were not included in this assessment. Despite the limitations of this study, this analysis provides valuable evidence regarding the increased burden of post-gastrectomy complications on healthcare resources.

CONCLUSION

Surgical resection of gastric cancer has a large cost impact and this is magnified in those patients who have post-operative complications. Key drivers of higher cost are the operating room, nursing care, ICU resources and bed days. These are potential opportunities to consider

quality initiatives and potential cost containment. This study emphasises the importance of exceptional inpatient care to minimise morbidity after gastrectomy.

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APPENDIX

Table 1: Costing buckets

Costing Buckets	Definition
Allied Health	Services related to physiotherapists, occupational therapists, social workers and dieticians.
CCU	Patients admitted to coronary care unit and requiring ongoing care at this facility.
Emergency	Patients admitted via the emergency department, however any imaging or pathology costs will be represented in the 'Pathology' and 'Radiology' cost bucket.

Endoscopy	Services related to endoscopy suite.
ICU	Patients admitted to the intensive care unit and requiring ongoing care at this facility.
Nursing	Services related to nursing care, and consumable costs from the wards.
Operating theatre	Operating theatre costs, including prosthetics, as well as nursing and anaesthetic care in the theatre and recovery setting.
Pathology	Services related to processing of pathology, including biochemistry, haematology and microbiology.
Pharmacy	Services related to dispensed medications identified at the patient level, as well as imprest drugs on the ward which are spread across all patients driven on length of stay.
Radiology	Services related to any form of imaging, including x-rays, computed tomography, ultrasound, fluoroscopy, positron emission tomography, nuclear medicine and interventional radiology.
Surgical operative care	Medical staff costs assigned to patients in the operating theatre, such as surgeon time spent in theatre.
Surgical ward care	Medical staff costs assigned to patients on the ward, such as surgical team care of patients in this setting.

Table 2: Patient demographics: Clinical, operative and pathological characteristics of cohort

Characteristic	Cohort, Number (%)
Age (Mean ± SD)	67.78 ± 12.31
Pre-operative BMI (Mean ± SD)	26.46 ± 6.97
Gender	
Male	43 (58.1)
Female	31 (41.9)
Charlson Comorbidity Index (Mean ± SD)	4.22 ± 2.16
Diabetes mellitus	
Yes	15 (20.3)
No	59 (79.7)
Congestive cardiac failure	
Yes	2 (2.7)
No	72 (97.3)
Chronic pulmonary disease	
Yes	3 (4.1)
No	71 (95.9)

Eastern Cooperative Oncology Group Status	
0	18 (28.6)
1	35 (55.6)
2	5 (7.9)
3	5 (7.9)
4	0 (0)
5	0 (0)
Unknown	11
American Society of Anaesthesiologists' Classification	
Grade I	4 (5.5)
Grade II	24 (32.9)
Grade III	42 (57.5)
Grade IV	3 (4.1)
Unknown	1
Smoking status	
Current	10 (13.5)
Former	28 (37.8)
Never	33 (44.6)
Unknown	3 (4.1)
Neoadjuvant therapy	
Yes	25 (34.2)
No	48 (65.8)
Unknown	1
Length of stay for index admission (Days), Mean ± SD	15.50 ± 10.57
Approach	
Laparoscopic	10 (13.5)
Laparoscopic converted to open	8 (10.8)
Open	56 (75.7)
Type of procedure	
Subtotal/Distal gastrectomy	43 (58.1)
Total gastrectomy	27 (36.5)
Extended total gastrectomy	4 (5.4)
Tumour histopathology	
Adenocarcinoma	68 (91.9)
Squamous cell carcinoma	1 (1.3)
Neuroendocrine	5 (6.8)
Tumour staging - *American Joint Committee on Cancer Staging System*	

0	4 (5.4)
I	11 (14.9)
II	20 (27.0)
III	31 (41.9)
IV	4 (5.4)
Unknown	4 (5.4)

** SD = Standard deviation; BMI = Body mass index; CCU = Coronary care unit; ICU = Intensive care unit*

Table 3: Total costing data for all patients.

Cost category	Median cost AUD$ (IQR)	Mean cost AUD$ ± SD	Proportion of total cost %	Minimum – Maximum cost AUD$
Allied health	1,366.45 (825.55 – 2,571.72)	2,011.01 ± 2,089.59	4.43%	313.73 – 12,831.75
CCU	0 (0 – 0)	12.69 ± 109.18	0.02%	0 – 935.16
Emergency	0 (0 – 0)	48.61 ± 171.04	0.09%	0 – 788.15
Endoscopy	0 (0 – 0)	79.61 ± 273.66	0.14%	0 – 1,567.87
ICU	0 (0 – 3,024.93)	4,585.08 ± 15,341.08	5.59%	0 – 122,079.51
Nursing	6,725.33 (5,433.76 – 10,831.82)	9,167.10 ± 6,375.28	22.95%	3,504.71 – 39,550.46
Operating theatre	12,805.82 (9,142.72 – 16,003.72)	12,896.92 ± 5,435.36	33.86%	3,475.83 – 27,541.97
Pathology	1,666.95 (1,114.03 – 2,733.95)	2,291.94 ± 2,157.29	5.18%	646.94 – 15.332.50
Pharmacy	1,079.48 (796.14 – 1,766.82)	1,767.70 ± 1,833.47	3.97%	496.98 – 8,895.78
Radiology	461.86 (116.90 – 1,490.00)	1,149.28 ± 1,505.28	2.20%	0 – 6,786.05
Surgical operative care	5,805.98 (4,005.68 – 8,647.60)	6,696.92 ± 4,406.24	16.70%	843.06 – 28,342.33

Surgical ward care	1,873.54 (886.19 – 2,821.50)	2,509.76 ± 2,872.01	4.89%	62.73 – 18,416.30
Total admission costs	36,437.95 (26,170.62 – 53,059.79)	43,216.63 ± 30,275.28		14,082.33 – 218,547.33

**AUD = Australian dollars (2019); IQR = Interquartile range; SD = Standard deviation; CCU = Coronary care unit; ICU = Intensive care unit*

Table 4: Costing data for post-operative complications, by severity.

Cost category	No complications, Median AUD$ (IQR) n = 36	Minor complications, Median AUD$ (IQR) (n = 21)	Major complications, Median AUD$ (IQR) (n = 17)	Significance (p-Value)
Allied health	1,088.64 (684.76 – 1,380.79)	1,577.07 (1,121.44 – 2,164.62)	2,708.25 (2,552.29 – 5,399.56)	p<0.001
CCU	0.00 (0.00 – 0.00)	0.00 (0.00 – 0.00)	0.00 (0.00 – 0.00)	p=0.283
Emergency	0.00 (0.00 – 0.00)	0.00 (0.00 – 0.00)	0.00 (0.00 – 0.00)	p=0.172
Endoscopy	0.00 (0.00 – 0.00)	0.00 (0.00 – 0.00)	0.00 (0.00 – 0.00)	p=0.689
ICU	0.00 (0.00 – 344.68)	0.00 (0.00 – 5,408.75)	3,000.64 (0.00 – 12,220.06)	p=0.007
Nursing	5,856.72 (4,372.19 – 6,541.89)	8,094.77 (6,703.19 – 11,033.18)	14,529.31 (7,977.45 – 23,303.42)	p<0.001
Operating theatre	11,879.03 (7,564.45 – 15,564.26)	11,725.71 (8,544.78 – 14,920.88)	14,144.77 (10,390.40 – 21,119.50)	p=0.091
Pathology	1,134.95 (903.78 – 1,468.30)	2,202.43 (1,639.16 – 2,786.96)	3,027.34 (1,874.86 – 5,485.97)	p<0.001
Pharmacy	822.72 (648.80 – 1,462.44)	1,065.51 (859.40 – 1,587.09)	2,283.34 (1,195.40 – 4,462.10)	p<0.001
Radiology	144.15 (0.00 – 520.54)	908.35 (203.70 – 2,099.85)	2,459.25 (1,091.29 – 3,623.40)	p<0.001
Surgical operative care	5,894.04 (3,064.15 – 8,613.93)	5,216.15 (2,823.46 – 8,894.14)	5,804.73 (5,422.35 – 8,660.65)	p=0.485
Surgical ward care	1,540.93 (393.77 – 1,960.63)	2,408.37 (216.48 – 2,749.39)	3,528.18 (2,387.72 – 6,604.06)	p<0.001

Total admission costs	29,228.37 (21,348.87 – 38,126.58)	36,592.29 (23,260.55 – 51,330.79)	71,807.60 (46,789.00 – 77,857.57)	p<0.001
Length of stay (Days)	9.00 (8.00 - 11.00)	14.00 (12.50 - 18.50)	21.00 (16.00 - 35.50)	p<0.001

**AUD = Australian dollars (2019); IQR = Interquartile range; CCU = Coronary care unit; ICU = Intensive care unit*

Figure 1: Costing data for patients complicated by anastomotic leak, distributed across different costing centres

**Cost presented as AUD = Australian dollars (2019); CCU = Coronary care unit; ICU = Intensive care unit*

Figure 1: Costing data for patients complicated by anastomotic leak, distributed across different costing centres