Scientific
Research

A Population-Based Outcomes Analysis of the Impact of Age on Morbidity and Mortality Following Gastrectomy: An Analysis of 13,799 Patients from the Nationwide Inpatient Sample Database

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ABSTRACT

Introduction: Gastric cancer is the 4th most common malignancy and second leading cause of cancer-related death worldwide, both its incidence and mortality have decreased over the past 70 years. Advancing life expectancy, as well as subtle change in the type and location of gastric cancer in the US, has resulted in an increased number of elderly patients requiring gastric surgery. By 2050, the population older than 85 years is projected to reach 20.9 million, and as a result, the need to assess the operative outcomes and mortality following gastrectomy in this group is imperative. This study sought to assess age-related clinical outcomes following gastric cancer surgery across all age groups to provide more precise data for pre-operative surgical risk stratification. **Methods:** Discharge data on 40,276,240 patients was collected from Nationwide Inpatient Sample Database (NIS) (2004-2008). Data on patients undergoing gastrectomy as the primary procedure was analyzed including age, gender, elective/non-elective admission, pre-operative length of stay (LOS), total LOS, and mortality. Eight age groups were compared for two procedures: total gastrectomy (TG) and partial gastrectomy (PG). Categorical data was compared using the Chi square test and continuous data using the Student's *t* test. Univariate analysis and multivariate regression analysis were performed to assess independent variables. **Results:** 13,799 patients underwent gastrectomy surgery with 23.7% having TG and 76.3% PG. Gastric carcinoma was the most common indication for TG, while benign gastric disease was more common for PG, especially in years 51 - 70 ($p < 0.001$).The mean age for TG and PG groups were 63 ± 12.8 and 64 ± 15 years respectively. Males underwent twice the number of TGs ($p < 0.001$), whereas equal number of males and females underwent PG ($p < 0.001$). The number of TGs increased over the 5-year study period, with the highest % change noted in those 41 - 50 years (1500%). PGs performed decreased overall, especially in patients <60 years, however PGs increased in patients >81 years with the greatest % change in the oldest patients >91 years (13%). Non-elective admissions were more common for PGs (N = 4844, 41%) than TGs (N = 695, 21.2%). Mean pre-operative LOS and total LOS increased with advancing age for both TG and PG ($p < 0.001$). HTN (45%), electrolyte imbalances (28%) and chronic pulmonary disease (18%) were the most prevalent co-morbidities and significantly affected mortality on univariate analysis ($p = 0.001$). Respiratory (18%) and GI complications (11%) were the most common post-operative complications following TG, while GI (9.6%) and bile duct fistulas (7.2%) were most common after PG. Overall TG and PG mortality rates were 7.6% and 6.4% respectively. Mortality increased with advancing age in both groups ($p < 0.001$). Multivariate analysis identified HTN, valvular disease, anemia, malignancy and non-elective admissions as independent predictors of mortality ($p = 0.001$). **Conclusions:** Advancing age is not an independent predictor of mortality following gastric surgery. Gastrectomy for gastric cancer is associated with a higher mortality than for benign gastric diseases. Non-elective admission, and pre-existing hypertension, valvular disease and anemia independently predicted increased morbidity and mortality following gastric surgery and should be carefully considered in surgical planning and counseling. Gastric carcinoma is the most common indication for TG, while benign gastric disease is a more common indication for PG. The number of TGs performed is increasing, especially in the males and younger patients, and may reflect an increased incidence of body and cardiac lesions.

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1. Introduction

Gastric cancer is the fourth most common malignancy and second leading cause of cancer-related death worldwide. Gastric cancer primarily presents in advanced stages especially among the elderly (>80 years) and is associated with a poor outcomes unless diagnosed early [1]. Hazanaki *et al.* observed advanced gastric cancer in 56% of patients >80 years compared to 27.9% of patients <80 years old ($p < 0.01$). Overall in-hospital mortality (2% versus 0%), and 5-year overall survival rates (46.1% versus 71.1% ($p < 0.01$)) were substantially higher among those >80 years compare those <80 years [2]. Precise explanations for the higher incidence of advanced disease and worse outcomes in the elderly remains largely unknown but is likely related to life expectancy, pre-existing co-morbidities, as well as age-related differences in tumor location and histology [3,4]. Complete surgical resection with a R0 margin provides the highest survival benefit for gastric cancer, however this is achievable in only a select group of patients (approximately 50%). Moreover, gastrectomy is associated with significant morbidity and mortality, particularly in the elderly, and in-hospital mortality rates as high as 16.6% after total gastrectomy (TG) and 15.3% after partial gastrectomy (PG) have been reported [5]. The percent of patients over 80 years is the fastest growing segment of the US population, and by 2050, those over 85 years is projected to reach 20.9 million. As a result, there is a growing and important need to have precise information related to the operative risks, outcomes and mortality following gastrectomy in elderly patients in order to improve surgical decision making and patient counseling. This study sought to compare population-based outcomes following gastrectomy across a wide range of age groups to determine whether advancing age, or other factors, were independently associated with increased morbidity and mortality.

2. Methods

Discharge data for 40,276,240 patients from the 2004-2008 Nationwide Inpatient Sample Database (NIS), a part of the Healthcare Cost and Utilization Project (HCUP) of the Agency for Healthcare Research and Quality (AHRQ) was analyzed. The NIS involved no identifying patient information and was thus exempt from Institutional Review Board approval at our institution. Information on patients who had undergone total gastrectomy (ICD 9 code: 439.1) and partial gastrectomy (ICD 9 codes: 438.1 and 438.9) as the primary procedure was abstracted. Eight age groups (in increments of 10 years starting at 21 years) were compared for two procedures: total gastrectomy (TG) and partial gastrectomy (PG). The number of patients, gender ratio, most common primary diagnosis, non-elective nature of admission, co-morbidities, pre-operative length of stay (LOS), total length of stay (LOS), and morbidity and mortality rates were abstracted separately for both TG and PG. Information on complication rates was extracted using ICD-9 codes. The type of complications and their broad grouping is detailed in **Table 1**. In addition, the total number of procedures performed (both TG and PG) over the five year period, as well as the percentage change in the number of procedures for each type of gastrectomy (**Figures 1(a)** and **(b)**), were calculated by dividing the number of gastrectomies performed in 2008 by the number gastrectomies performed in 2004.

Statistical analysis was performed using the Chi square test for categorical data and the Student's t test for continuous data. A value of $p < 0.05$ was considered statistically significant. Univariate analysis and multivariate logistic regression analysis were performed to assess factors affecting mortality following gastrectomy. Data analysis was performed using SPSS version 19.0 (SPSS, Inc). As per NIS database reporting guidelines, values <10 are not shown in the results section and in the tables.

3. Results
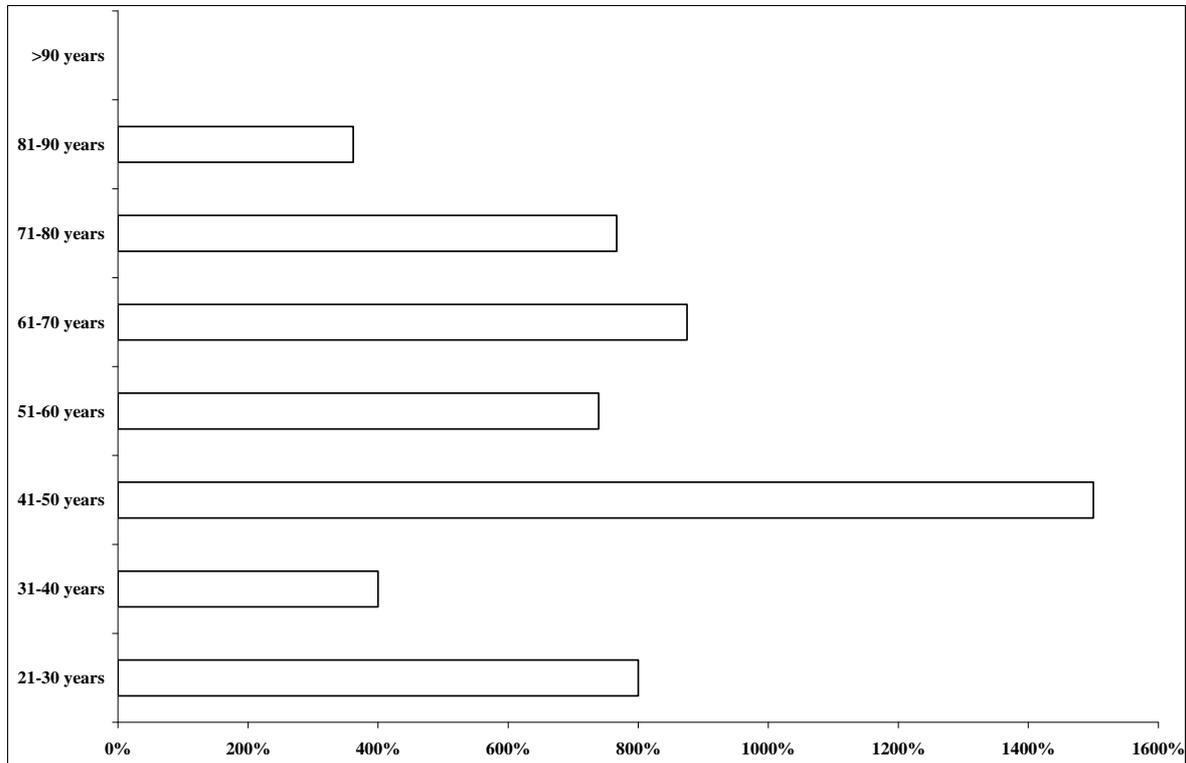
3.1. Demographic Information

13,799 patients identified in the NIS underwent either total gastrectomy (TG) or partial gastrectomy (PG) between 2004 and 2008, and formed the study population. Clinicopathological characteristics are detailed in **Table 2**. 23.7% (N = 3271) patients underwent a TG, while 76.3% (N = 10,528) underwent a PG. The largest number of TG were performed in patients age 61 - 70 years (N = 980, 30%), whereas the largest number of PG were performed in those age 71 - 80 years (N = 2436, 23.1%). The mean age for the TG and PG groups were 63.1 ± 12.8 and 64.1 ± 15 years, respectively. Twice the number of males compared to females received a TG ($p < 0.001$), whereas equal numbers received a PG ($p < 0.001$). The greatest gender difference was observed among those 61 - 70 years old for the TG group (M:F, 2.9:1), and among those 21 - 30 for the PG group (M:F, 1:1.6). **Figures 1(a)** and **(b)** detail the change in number and percent of TG and PG performed during the study period. TGs increased over the 5-year study period, with the highest percentage change among those 41 - 50 years (1500%). The number of PGs performed decreased overall, especially in patients aged <60 years, but it increased among patients >80 years with the highest percentage change noted in patients >90 years (13%).
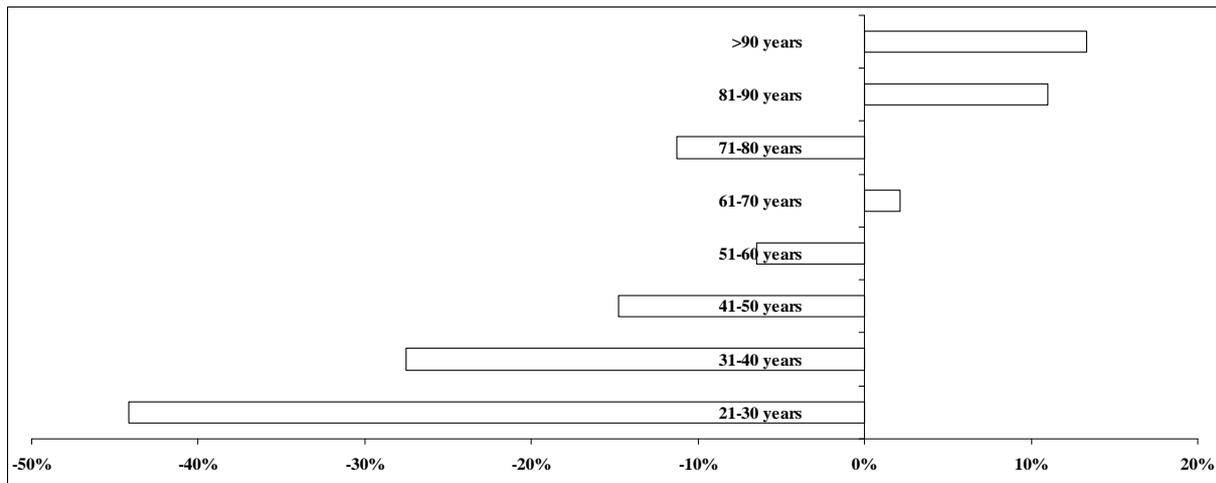
3.2. Pathology and Co-Morbidities

Gastric carcinoma was the most common indication for

Table 1. Complications studied by ICD code and their broad grouping for analysis (national inpatient sample database 2004-2008).

Broad group	ICD 9 code	Complication	Components
Medical complications			
Respiratory complications	512.1 415.11 518.5 518.4 997.31 997.39	Iatrogenic pneumothorax Iatrogenic pulmonary embolic infarct Post traumatic pulmonary insufficiency Acute lung edema NOS Ventilator associated pneumonia Respiratory complications NEC	
Cardiac complications	997.1	Post-operative complications of Heart	Cardiac arrest during or resulting from a procedure Cardiac insufficiency during or resulting from a procedure Cardiorespiratory failure during or resulting from a procedure Heart failure during or resulting from a procedure
Post-operative stroke	997.02	Post-operative stroke (Begins 1995)	
Urinary tract complications	997.5	Post-operative complications of urinary tract	Complications of: External stoma of urinary tract Internal anastomosis and bypass of urinary tract, including that involving intestinal tract Oliguria or anuria specified as due to procedure Renal failure (acute) specified as due to procedure Insufficiency (acute) specified as due to procedure Tubular necrosis (acute) specified as due to procedure
Sepsis	995.91		Intra-abdominal post-operative Stitch post-operative Subphrenic post-operative Wound post-operative
Surgical complications			
Gastrointestinal complications	997.4	Post-operative complications of GI tract	Complications of: intestinal (internal) anastomosis and bypass, not elsewhere classified, except that involving urinary tract Hepatic failure specified as due to a procedure Hepatorenal syndrome specified as due to a procedure Intestinal obstruction NOS specified as due to a procedure
Fistula of bile duct	576.4	Fistula of bile duct	
Post-operative infection	998.59	Other post-operative infection	Abscess: post-operative
Accidental operative laceration	998.2	Accidental operative laceration	Accidental perforation by catheter or other instrument during a procedure on: Blood vessel, Nerve, Organ
Post-operative hemorrhage	998.11	Post-operative hemorrhage	
Disruption of internal operative wound	998.31	Disruption of internal operative wound	
Disruption of external operative wound	998.32	Disruption of external operative wound	
Intestinal fistula	569.81	Intestinal fistula	
Deep vein thrombosis	453.9 453.40 453.41 453.42	Venous thrombosis NOS DVT/Embolism lower ext NOS DVT/Embolism proximal lower ext DVT/Embolism distal lower ext	

(a)

(b)

Figure 1. (a) Percentage change in the number of total gastrectomy performed among all age groups between 2004-2008 (national inpatient sample database); (b) percentage change in the number of partial gastrectomy among all age groups between 2004-2008 (national inpatient sample database).

TG overall (87.5%) and in each age group. Benign disease was the most common indication for PG overall (57%) and for all patients under 70 years. Gastric carcinoma was the most common indication for PG in patients >70 years (**Table 3(a)**). An increasing number of PGs were performed for both malignant and benign disease with advancing age, while an increasing percentage of TGs compared to PGs were performed in younger patients (primarily in those with malignant disease). (**Table 3(a)**) Over the course of the study, there was an increasing trend in the number of patients operated upon for gastric cancer, with a corresponding decrease in the number of patients operated upon for benign disease in all but the seventh and tenth decades (**Table 3(b)**). Gastroesophageal junction (GEJ) or abdominal esophagus carcinoma was the most indication for total gastrectomy in all age

Table 2. Clinicopathological data on 13,799 patients undergoing total and partial gastrectomy (national inpatient sample database 2004-2008).

	Overall	Patients' Age Groups by Decade								p value*
		21 - 30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80	81 - 90	>91	
Total Gastrectomy										
N, (%)	3271	32 (1.0)	110 (3.4)	356 (10.9)	733 (22.4)	980 (30.0)	802 (24.5)	250 (7.6)	(-)	
Male: Female ratio	2.1: 1	0.9: 1	1.2: 1	1.7: 1	2.2: 1	2.9: 1	2.1: 1	1.7: 1	1:01	0.001
Non-elective admission, N (%)	695 (21.2)	11 (34.4)	25 (22.7)	66 (18.5)	152 (20.7)	174 (17.8)	168 (20.9)	94 (37.6)	(-)	0.001
Pre-operative LOS, mean ± SD	1.2 ± 3.8	1.8 ± 4.6	0.7 ± 2.6	1.0 ± 3.1	1.0 ± 2.8	1.0 ± 3.5	1.5 ± 5.0	2.3 ± 4.1	6.4 ± 5.6	0.001
Total LOS, mean ± SD	16.5 ± 14.7	16.2 ± 16.7	13.5 ± 9.3	14.8 ± 12.7	15.5 ± 13.2	16.7 ± 15.4	17.7 ± 15.4	18.7 ± 17.0	17.4 ± 8.5	0.001
Mortality, N (%)	250 (7.6)	(-)	(-)	11 (3.1)	39 (5.3)	60 (6.1)	88 (11.0)	45 (18.0)	(-)	0.003
Partial Gastrectomy										
N, (%)	10,528	153 (1.5)	531 (5.0)	1336 (12.7)	2158 (20.5)	2349 (22.3)	2436 (23.1)	1429 (13.6)	136 (1.3)	
Male: Female ratio	1:1.1	1:1.6	1:1.5	1:1.3	1:1.1	1:0.9	1:1.0	1:1.3	1:1.4	0.001
Non-elective admission, N (%)	4884 (46.5)	87 (56.9)	246 (46.4)	567 (42.5)	932 (43.4)	1001 (42.7)	1142 (46.9)	820 (57.5)	89 (65.4)	0.001
Pre-operative LOS, mean ± SD	2.1 ± 4.4	2.6 ± 5.1	2.3 ± 8.5	1.7 ± 3.6	2.0 ± 4.2	1.9 ± 3.9	2.2 ± 4.0	2.9 ± 4.4	3.3 ± 4.3	0.001
Total LOS, mean ± SD	13.9 ± 13.4	13.7 ± 18.3	11.7 ± 17.8	12.2 ± 11.9	12.9 ± 13.3	13.9 ± 13.2	14.9 ± 13.6	16.1 ± 12.2	15.8 ± 9.8	0.001
Mortality, N (%)	670 (6.4)	(-)	(-)	31 (2.3)	61 (2.8)	135 (5.7)	199 (8.2)	206 (14.4)	27 (19.9)	0.001

Abbreviations: N: number of patients; LOS: length of stay; SD: standard deviation; (-): As per NIS database reporting guidelines, values <10 are not shown in the table; *p value < 0.05 statistical significance for the range.

Table 3. (a) Distribution of malignant and benign cases in 13,799 patients undergoing total and partial gastrectomy separated according to patient age groups by decades (national inpatient sample database 2004-2008); (b) Distribution of malignant and benign cases in 13,799 patients undergoing total and partial gastrectomy separated according to patient age groups by decades and year of study period (national inpatient sample database 2004-2008).

(a)

Age groups	Main Group				p value*
	Malignant disease, N (%)		Benign disease, N (%)		
	Total gastrectomy	Partial gastrectomy	Total gastrectomy	Partial gastrectomy	
21 - 30	19 (50.0)	19 (50.0)	13 (8.8)	135 (91.2)	0.001
31 - 40	79 (40.7)	115 (59.3)	31 (6.9)	420 (93.1)	0.001
41 - 50	280 (43.1)	370 (56.9)	76 (7.3)	970 (92.7)	0.001
51 - 60	634 (47.3)	706 (52.7)	99 (6.3)	1462 (93.7)	0.001
61 - 70	884 (45.1)	1074 (54.9)	96 (7.0)	1284 (93.0)	0.001
71 - 80	736 (35.0)	1367 (65.0)	66 (5.8)	1075 (94.2)	0.001
81 - 90	222 (20.7)	849 (79.3)	28 (4.6)	583 (95.4)	0.001
>90	(-)	74 (90.2)	0 (0)	63 (100.0)	0.001

Abbreviations: N: number of patients; (-): As per NIS database reporting guidelines, values <10 are not shown in the table; *p value < 0.05 statistical significance for the range.

(b)

Age Groups	Number of Malignant and Benign cases during study period (2004-2008)									
	Malignant disease, N (%)					Benign disease, N (%)				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
21 - 30	(-)	12 (31.6)	(-)	7 (18.4)	8 (21.1)	43 (29.1)	28 (18.9)	19 (12.8)	32 (21.6)	26 (17.6)
31 - 40	26 (13.4)	40 (20.6)	41 (21.1)	47 (24.2)	40 (20.6)	130 (28.8)	86 (19.1)	74 (16.4)	68 (15.1)	93 (20.6)
41 - 50	76 (11.7)	143 (22.0)	101 (15.5)	162 (24.9)	168 (25.8)	242 (23.1)	215 (20.6)	195 (18.6)	184 (17.6)	210 (20.1)
51 - 60	154 (11.5)	283 (21.1)	268 (20.0)	331 (24.7)	304 (22.7)	344 (22.0)	295 (18.9)	320 (20.5)	268 (17.2)	334 (21.4)
61 - 70	237 (12.1)	397 (20.3)	433 (22.1)	432 (22.1)	459 (23.4)	267 (19.3)	286 (20.7)	269 (19.5)	256 (18.6)	302 (21.9)
71 - 80	279 (13.3)	474 (22.5)	422 (20.1)	468 (22.3)	460 (21.9)	258 (22.6)	240 (21.0)	208 (18.2)	231 (20.2)	204 (17.9)
81 - 90	158 (14.8)	230 (21.5)	210 (19.6)	219 (20.4)	254 (23.7)	129 (21.1)	140 (22.9)	129 (21.1)	103 (16.9)	110 (18.0)
>90	17 (20.7)	12 (14.6)	18 (22.0)	13 (15.9)	22 (26.8)	13 (20.6)	(-)	14 (22.2)	11 (17.5)	15 (23.8)

Abbreviations: N: number of patients; (-): As per NIS database reporting guidelines, values <10 are not shown in the table.

groups (59.2%), whereas partial gastrectomy for malignancy was most commonly performed for antral or pyloric tumors (47.2%) in all age groups (**Table 4**). Overall, 15.1% of gastrectomies were performed for GEJ/abdominal esophagus tumors, while 17.5% were performed for antral tumors. Elective admissions were far more common in the TG group (N = 2576, 78.8%) compared to the PG group (N = 5648, 53.6%) with more non-elective admissions occurring in the both the youngest and oldest age groups (**Table 2**). The three most common co-morbidities overall were hypertension (TG; 43.7% vs. PG; 45.5%), fluid and electrolyte imbalances (TG; 27%) vs. PG; 28.1%), and chronic pulmonary disease (TG; 9.9% vs. PG; 18.2%). (**Tables 5(a)** and **(b)**) The percentage of patients with hypertension and fluid and electrolyte imbalances was highest in those >80 years for both the TG and PG groups. Chronic pulmonary disease occurred most commonly in those aged 71 - 80 years for both the TG and PG groups, but occurred with high frequency in all patients >70 years (~19% - 26%).

3.3. Complications

Complications in the TG and PG groups are detailed in **Tables 6(a)** and **(b)**. The overall complication rate was 54% in the TG group and 36% in the PG group. The most common complications in the TG group were respiratory (18%) and gastrointestinal (GI) (11.4%), with the highest percent of complications occurring in those >51 years. An increasing number of respiratory complications were seen with advancing age, with those age 21 - 30 years having those lowest incidence (9.4%) and those >91 having the highest (25%). The age-related trend in GI complications (intestinal obstruction and anastomotic and hepatic complications) noted. Among PG patients, GI complications (9.6%) and bile duct fistulas (7.2%)

were most common peaking incidence among those 61 - 70 years. Similar to the TG group, no appreciable age-related trend in GI complications was noted in the PG group. There was an increase age-related incidence in bile duct fistulas in the PG group ranging from 2% in those 21 - 30 years to 13.2% in those >91 years. Cardiac events occurred more commonly in the TG groups with the highest incidence in those 61 - 70 (7.7%) and 71 - 80 years old (8.1%) ($p < 0.001$). The overall cardiac complication rate in the PG group (3.2%) was half of that observed in the TG group (6.1%) ($p < 0.001$).

3.4. Clinicopathological Data and Mortality

Clinical outcomes from the two surgery groups are detailed in **Table 2**. 59.5% of all admissions for gastric surgery were elective, including 78.8% of TGs and 53.6% of PGs ($p = 0.001$). Elective admission status did not different for the PG groups, but was highest in those >81 years old. Elective admission status was far more common in those <80 years old undergoing TG compared to those >81 years old ($p = 0.001$). The mean pre-operative and total hospital LOS generally increased with advancing age for both the TG and PG with the exception of the youngest age group (age 21 - 30 years) whose LOS equaled those >61 years ($p < 0.001$). The overall mortality rate for all gastrectomy patients in the study groups was 6.7% (**Table 7**). The mortality rate for the TG group was 7.6%, while the mortality rate for the PG group was 6.4% ($p = 0.01$) (**Table 2**). Mortality rates increased in a linear fashion with advancing age also for both TG and PG beginning with those >30 years of age (**Table 2**). However, it is notable that the youngest group had a mortality rate higher than (TG group) or similar to (PG group) those aged 51 - 60 years ($p < 0.001$) (**Table 7**). The highest mortality rate of 20% was

Table 4. Anatomic site of malignancy in 13,799 patients undergoing total and partial gastrectomyseparated according to patient age groups by decades (national inpatient sample database 2004-2008).

Site of Malignancy	Total Gastrectomy, N (%)									Partial Gastrectomy, N (%)								
	Overall	21 - 30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80	81 - 90	>91	Overall	21 - 30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80	81 - 90	>91
Lower 1/3rd and Abdominal Esophagus	422 (15.6)	0	11 (13.6)	41 (16)	100 (16.8)	150 (18.2)	94 (13.7)	26 (11.7)	0	59 (1.3)	0	(-)	(-)	18 (2.5)	22 (2.1)	(-)	(-)	0
GE Junction	1176 (43.6)	(-)	30 (37)	106 (41.4)	279 (46.9)	388 (47.1)	296 (43.1)	70 (31.5)	(-)	428 (9.4)	(-)	(-)	41 (11.2)	69 (9.8)	99 (9.2)	143 (10.4)	63 (7.4)	(-)
Gastric Body	167 (6.2)	(-)	(-)	18 (7.0)	21 (3.5)	40 (4.9)	59 (8.6)	20 (9)	(-)	483 (10.6)	(-)	15 (13.3)	38 (10.4)	76 (10.7)	101 (9.4)	168 (12.2)	73 (8.6)	(-)
Antrum/ Pyloric/ Pre-pyloric Tumor	261 (9.7)	(-)	(-)	28 (10.9)	64 (10.8)	75 (9.1)	53 (7.7)	27 (12.2)	(-)	2159 (47.2)	(-)	53 (46.9)	158 (43.3)	299 (42.3)	526 (49.1)	662 (48.1)	414 (48.7)	41 (55.4)

Abbreviations: N: number of patients; GE: gastroesophageal; NEC: not elsewhere classified; NOS: not otherwise specified; (-): As per NIS database reporting guidelines, values <10 are not shown in the table.

Table 5. (a) Distribution of co-morbidities in 3271 patients undergoing total gastrectomy separated according to patient age groups by decades (national inpatient sample database 2004-2008); (b) distribution of co-morbidities in 10,528 patients undergoing partial gastrectomy separated according to patient age groups by decades (national inpatient sample database 2004-2008).

(a)

Co-morbidities	Overall	Patients' Age Groups by Decades, N (%)								p value[*]
		21 - 30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80	81 - 90	>91	
Hypertension	1429 (43.7)	(-)	(-)	72 (20.2)	291 (39.7)	473 (48.3)	438 (54.6)	138 (55.2)	(-)	0.001
Fluid and electrolyte imbalances	882 (27.0)	(-)	27 (24.5)	74 (20.8)	173 (23.6)	284 (29.0)	224 (27.9)	87 (34.8)	(-)	0.001
Chronic pulmonary disease	651 (19.9)	(-)	(-)	52 (14.6)	114 (15.6)	211 (21.5)	212 (26.4)	48 (19.2)	(-)	0.001
Weight loss	480 (14.7)	(-)	15 (13.6)	48 (13.5)	92 (12.6)	134 (13.7)	132 (16.5)	53 (21.2)	(-)	0.043
Obesity	186 (5.7)	0	(-)	26 (7.3)	65 (8.9)	58 (5.9)	28 (3.5)	5 (2.0)	0	0.001
Coagulopathy	143 (4.4)	(-)	(-)	10 (2.8)	25 (3.4)	41 (4.2)	44 (5.5)	19 (7.6)	(-)	0.017
Chronic blood loss anemia	143 (4.4)	(-)	(-)	(-)	30 (4.1)	34 (3.5)	52 (6.5)	18 (7.2)	0	0.001
Renal failure	118 (3.6)	(-)	(-)	(-)	19 (2.6)	33 (3.4)	41 (5.1)	18 (7.2)	0	0.001
Alcohol abuse	104 (3.2)	(-)	(-)	16 (4.5)	37 (5.0)	31 (3.2)	17 (2.1)	0	0	0.002
Liver disease	75 (2.3)	0	(-)	11 (3.1)	17 (2.3)	18 (1.8)	22 (2.7)	(-)	0	0.76
Diabetes	47 (1.4)	(-)	(-)	(-)	15 (2.0)	13 (1.3)	12 (1.5)	(-)	(-)	0.83

Abbreviations: N: number of patients; (-): As per NIS database reporting guidelines, values <10 are not shown in the table; [*]p value < 0.05 statistical significance for the range.

(b)

Co-morbidities	Overall	Patients' Age Groups by Decades, N (%)								p value[*]
		21 - 30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80	81 - 90	>91	
Hypertension	4875 (45.5)	24 (15.6)	103 (19.1)	344 (25.2)	888 (40.5)	1224 (51.0)	1415 (57.2)	792 (54.9)	85 (62.0)	0.001
Fluid and electrolyte imbalances	3011 (28.1)	31 (20.1)	106 (19.7)	302 (22.1)	536 (24.4)	642 (26.8)	789 (31.9)	539 (37.4)	66 (48.2)	0.001
Chronic pulmonary disease	1949 (18.2)	12 (7.8)	55 (10.2)	184 (13.5)	364 (16.6)	487 (20.3)	549 (22.2)	270 (18.7)	28 (20.4)	0.001
Weight loss	1430 (13.4)	19 (12.3)	67 (12.4)	163 (11.9)	243 (11.1)	307 (12.8)	352 (14.2)	257 (17.8)	22 (16.1)	0.001
Chronic blood loss anemia	1016 (9.5)	12 (7.8)	47 (8.7)	99 (7.3)	175 (8.0)	223 (9.3)	259 (10.5)	186 (12.9)	15 (10.9)	0.001
Obesity	548 (5.1)	(-)	43 (8.0)	102 (7.5)	159 (7.2)	131 (5.5)	71 (2.9)	30 (2.1)	(-)	0.001
Renal failure	543 (5.1)	(-)	12 (2.2)	37 (2.7)	63 (2.9)	107 (4.5)	173 (7.0)	130 (9.0)	16 (11.7)	0.001
Coagulopathy	471 (4.4)	(-)	13 (2.4)	41 (3.0)	79 (3.6)	95 (4.0)	139 (5.6)	89 (6.2)	(-)	0.001
Liver disease	396 (3.7)	(-)	32 (5.9)	65 (4.8)	115 (5.2)	87 (3.6)	69 (2.8)	19 (1.3)	(-)	0.001
Alcohol abuse	379 (3.5)	(-)	24 (4.5)	93 (6.8)	102 (4.6)	89 (3.7)	57 (2.3)	(-)	(-)	0.001
Diabetes	197 (1.8)	(-)	(-)	(-)	38 (1.7)	59 (2.5)	59 (2.4)	26 (1.8)	(-)	0.001

Abbreviations: N: number of patients; (-): As per NIS database reporting guidelines, values <10 are not shown in the table; [*]p value < 0.05 statistical significance for the range.

Table 6. (a) Distribution of post-operative complications in 3271 patients undergoing total gastrectomy separated according to patient age groups by decades (national inpatient sample database 2004-2008); (b) Distribution of post-operative complications in 10,528 patients undergoing partial gastrectomy separated according to patient age groups by decades (national inpatient sample database 2004-2008).

(a)

Complications	Patients' Age Groups by Decade, N (%)							
	Overall	21 - 30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80	81 - 90	>91
Medical Complications									
Respiratory complications	590 (18.0)	(-)	12 (10.9)	44 (12.4)	117 (16.0)	207 (21.1)	158 (19.7)	47 (18.8)	(-)
Cardiac complications	201 (6.1)	(-)	(-)	15 (4.2)	29 (4.0)	75 (7.7)	65 (8.1)	12 (4.8)	0
Urinary complications	47 (1.4)	0	1 (0.9)	(-)	(-)	13 (1.3)	16 (2.0)	(-)	(-)
Post-operative stroke	5 (0.2)	0	0	(-)	0	(-)	(-)	0	0
Sepsis	3 (0.09)	0	0	0	0	(-)	0	0	0
Surgical Complications									
Gastrointestinal complications	374 (11.4)	(-)	12 (10.9)	42 (11.8)	85 (11.6)	120 (12.2)	85 (10.6)	28 (11.2)	(-)
Other post-operative infection	208 (6.4)	(-)	(-)	25 (7.0)	45 (6.1)	74 (7.6)	44 (5.5)	13 (5.2)	0
Accidental laceration during a procedure	112 (3.4)	0	(-)	14 (3.9)	29 (4.0)	36 (3.7)	19 (2.4)	9 (3.6)	(-)
Post-operative Hemorrhage	83 (2.5)	(-)	(-)	12 (3.4)	17 (2.3)	19 (1.9)	23 (2.9)	9 (3.6)	0
Venous thrombosis	53 (1.6)	0	(-)	(-)	(-)	20 (2.0)	15 (1.9)	(-)	0
Disruption of external operation wound	39 (1.2)	0	(-)	(-)	(-)	20 (2.0)	-	0	0
Disruption of internal operation wound	35 (1.1)	0	0	(-)	(-)	(-)	12 (1.5)	(-)	0
Intestinal fistula	3 (0.1)	0	0	0	(-)	0	-	0	0

Abbreviations: N: number of patients; (-): As per NIS database reporting guidelines, values <10 are not shown in the table.

(b)

Complications	Patients' Age Groups by Decades, N (%)							
	Overall	21 - 30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80	81 - 90	>91
Medical Complications									
Cardiac Complications	333 (3.2)	(-)	(-)	15 (1.1)	40 (1.9)	61 (2.6)	105 (4.3)	91 (6.4)	12 (8.8)
Respiratory Complications	160 (1.5)	(-)	(-)	21 (1.6)	27 (1.3)	46 (2)	31 (1.3)	24 (1.7)	(-)
Urinary Tract Complications	97 (0.9)	0	(-)	(-)	18 (0.8)	23 (1.0)	27 (1.1)	20 (1.4)	(-)
Post-operative Stroke	22 (0.21)	0	0	(-)	(-)	(-)	(-)	(-)	0
Sepsis	18 (0.17)	0	0	0	(-)	(-)	(-)	(-)	0
Surgical Complications									
Gastrointestinal Complications	1013 (9.6)	10 (6.5)	44 (8.3)	128 (9.6)	199 (9.2)	230 (9.8)	234 (9.6)	158 (11.1)	10 (7.4)
Fistula of bile duct	763 (7.2)	(-)	19 (3.6)	61 (4.6)	99 (4.6)	190 (8.1)	209 (8.6)	164 (11.5)	18 (13.2)
Post-operative infections	568 (5.4)	10 (6.5)	21 (4.0)	71 (5.3)	123 (5.7)	137 (5.8)	119 (4.9)	76 (5.3)	11 (8.1)
Accidental operative laceration	266 (2.5)	0	15 (2.8)	31 (2.3)	50 (2.3)	63 (2.7)	67 (2.8)	34 (2.4)	(-)
Post-operative hemorrhage	220 (2.1)	(-)	12 (2.3)	26 (1.9)	35 (1.6)	61 (2.6)	47 (1.9)	34 (2.4)	(-)
Disruption of external operation wound	103 (1.0)	(-)	(-)	11 (0.8)	23 (1.1)	24 (1.0)	22 (0.9)	15 (1.0)	(-)
Disruption of internal operation wound	69 (0.7)	(-)	(-)	11 (0.8)	18 (0.8)	18 (0.8)	12 (0.5)	(-)	(-)
Intestinal fistula	29 (0.28)	0	(-)	(-)	(-)	(-)	(-)	(-)	0
Deep vein thrombosis	98 (0.9)	0	(-)	(-)	11 (0.5)	20 (0.9)	35 (1.4)	23 (1.6)	(-)

Abbreviations: N: number of patients; (-): As per NIS database reporting guidelines, values <10 are not shown in the table.

Table 7. Univariate analysis of in-hospital mortality for 13,799 patients undergoing total and partial gastrectomy (national inpatient sample database 2004-2008).

Variable	Mortality rate, %	p value[*]
Overall	6.7	
Age groups		0.001
21 - 30 years	3.8	
31 - 40 years	1.4	
41 - 50 years	2.5	
51 - 60 years	3.4	
61 - 70 years	5.9	
71 - 80 years	8.9	
81 - 90 years	15.0	
>90 years	20.0	
Gender		0.002
Male	7.3	
Female	6.0	
Race		0.015
Native American	10.2	
White	7.3	
Hispanic	6.3	
Black	5.7	
Asian or Pacific Islander	5.1	
Others	3.7	
Type of gastrectomy		0.011
Total gastrectomy	7.6	
Partial gastrectomy	6.4	
Indications for gastrectomy		0.001
Benign disease	8.0	
Malignant disease	5.6	
Type of admission		0.001
Non-elective admission	11.4	
Elective admission	3.5	
Co-morbidities		
Coagulopathy	25.2	0.001
Renal failure	19.3	0.001
Congestive heart failure	19.1	0.001
Fluid and electrolyte disorders	13.0	0.001
Liver disease	12.4	0.001
Peripheral vascular disorders	12.0	0.001
Weight loss	11.6	0.001
Diabetes with chronic complications	9.9	0.042
Alcohol abuse	9.9	0.005
Chronic blood loss anemia	9.1	0.001
Valvular disease	8.5	0.059
Chronic pulmonary disease	8.4	0.001
Diabetes, uncomplicated	5.9	0.129
Hypertension (combine uncomplicated and complicated)	5.5	0.001

[*]p value < 0.05 statistical significance for the range.

seen in those >91 years old ($p < 0.001$).

3.5. Univariate and Multivariate Analysis

Univariate analysis identified several patient factors which impacted mortality rates. (**Table 7**) Specifically, mortality rates were significantly higher among patients >90 years (20%) ($p = 0.001$), male patients (7.3%) ($p = 0.002$), Native Americans (10.2%) ($p = 0.015$), those having a gastrectomy for benign disease (8%) ($p = 0.001$), and patients with non-elective admission status prior to gastrectomy (11.4%) ($p = 0.001$). In addition, the presence of several co-morbidities also increased mortality rates including coagulopathy (25.2%), renal failure (19.3%), congestive heart failure (19.1%) and fluid and electrolyte imbalances (13%). On multivariate analysis (**Table 8**), age did not independently impact mortality and only non-elective admission ($p = 0.001$), hypertension ($p = 0.001$), valvular heart disease ($p = 0.001$), anemia ($p = 0.001$), and gastric cancer ($p = 0.001$) increased in-hospital mortality in patients undergoing gastrectomy.

4. Discussion

Today approximately 21,000 Americans are diagnosed annually with gastric cancer and half will die due to the lethality of the disease. It has been predicted that the proportion of the US population over 80 years old is expected to double in the next two decades going from 5% (1990) to 10% (2030) [6]. In addition, Americans 65 to 79 years who constituted 9.3% of the population in 2000, are projected to increase to 12.5% by 2050 and 12.9% by 2070 [7]. Given current life table analysis, which predicts that patients who survive to the age of 80 - 85 years old will live another 8 years on average, the number of elderly patients (>80 years)—and as a result the number of patients overall who will require gastric surgery—is increasing and will increase exponentially in the future [8,9]. Despite these facts, little is known about the clinical outcomes of gastrectomy for either benign or malignant conditions in elderly patients, as they are largely excluded from clinical trials given their presumed "high risk" status. More precisely, increased severity and frequency of co-morbidities, malnutrition and diminished organ reserve in the elderly and their demonstrable import on post-operative morbidity and mortality, has led to significant surgical bias towards performing less radical procedures or failure to consider the elderly for gastric surgery at all. Recently identified epidemiological shifts, from distal intestinal type to proximal diffuse type adenocarcinoma of the gastric cardia, most notably in the elderly patients and Western countries, may further complicate this picture [10,11]. At present, the best available data on the outcomes of gastric surgery in the elderly are

Table 8. Multi-variate analysis of in-hospital mortality for 13,799 patients undergoing total and partial gastrectomy (national inpatient sample database 2004-2008).

Variable	Overall		Total gastrectomy		Partial gastrectomy	
	OR (95% C.I.)	p value	OR (95% C.I.)	p value	OR (95% C.I.)	p value[*]
Hypertension	1.7 (1.4 - 2.0)	0.001	1.7 (1.2 - 2.4)	0.001	1.7 (1.4 - 2.1)	0.001
Valvular heart disease	1.6 (1.1 - 2.3)	0.001			1.5 (1.0 - 2.3)	0.001
Anemia	1.5 (1.2 - 1.8)	0.001			1.5 (1.2 - 1.9)	0.001
Non-elective admission	2.4 (2.0 - 2.9)	0.001	2.7 (1.9 - 3.7)	0.001	2.4 (1.9 - 3.1)	0.001
Gastric cancer	1.6 (1.3 - 2.0)	0.001	2.0 (1.3 - 3.2)	0.001	1.6 (1.2 - 2.0)	0.001

Abbreviations: OR: odds ratio; C.I.: confidence interval; [*]p value < 0.05 statistical significance.

conflicting, lack inherent uniformity, and suffer primarily from the problem of small sample sizes and single institutional analysis [2,10,12-18].

Pisanu et al. evaluated 135 patients over 75 years old treated over an 11-year period, and determined that advanced age was not a contraindication to gastrectomy, nor was it predictive of increased morbidity and mortality (REF). These authors noted that the increased rate of co-morbidities and malnutrition were the primary factor contributing to increased mortality in the elderly rather than age alone. (REF) They also concluded that PG as opposed to TG was associated with improved quality of life (QOL) for this group, without sacrificing cure. Similar to these results Katai et al. noted significantly increased 30-day and 90-day mortality rates of 9.4% and 18.8% in patients >80 years undergoing TG compared to those 50 - 69 years (1.4% and 4.4%, p < 0.001) [11]. Among patients >80 years old undergoing PG, mortality rates were 0% and 3.7% compared to 0.5% and 1.7% in patients 50 - 69 years of age (p = N.S). [14] Most notably, PG was also associated with an improved long-term survival compared to TG [19,20]. Sánchez-Bueno et al. also reported improved five-year survival among patients undergoing PG (48.1%) compared to those undergoing TG (18%) (p = 0.001) [20]. However despite these encourage results, there remains no clear consensus on whether age alone independently affects morbidity and mortality after gastric surgery (and for that matter many surgeries). This is primarily due to the fact that most studies, in which increased mortality rates among the elderly have been reported, have failed to perform multivariate analysis allowing independent assessment of the contribution of advanced age [14]. In one of the few studies to perform multivariate analysis, Pisanu et al. reported a significantly higher mortality rate 17.2% following all types of gastrectomy in patients >75 years (17.2%) compared to patients <75 years (5.6%). However, they noted that several co-morbidities rather than age were the strongest predictors of increased post-operative mortality. Similar to the report by Pisanu et al., the current study also re-

ports higher mortality rates with advancing age, but age by itself was not an independent predictor of mortality alone. Rather, our data supports the notion that being "old" is not nearly as important as being "sick and old" when it comes to mortality following gastric surgery. Much like a machine that continues to function well despite age, if given the proper maintenance (on or off warranty), the old patient with neglected health or chronic conditions is at greatest risk of failure (or death) when stressed. While the current study is certainly limited to drawing conclusions based on the variables assessed, it is noteworthy that the presence of gastric cancer, and pre-existing hypertension, valvular disease, and anemia were all strongly associated with increased mortality. Of note, hypertension was the most prevalent co-morbid condition in those >50 years; while fluid and electrolyte imbalance was the most common co-morbidity in younger groups. These results are similar to those of Pisanu et al., who identified hypertension and stroke as the two most important factors affecting mortality following gastrectomy, as well as a report by Roviello et al. who noted that the two most common pre-existing conditions among patients undergoing surgery for gastric cancer were cardiovascular (57.7%) and anemia/hypoproteinemia (41%) [21,22]. The congruence of these findings across all three studies may be interpreted as implying that, whereas elderly patients are far more likely to have cardiovascular disease and suboptimal nutrition, particular attention to these co-morbidities, and optimization or remediation of these when possible, may result in decreased in-hospital mortality.

Several authors have reported that emergency surgery or non-elective gastric surgery (in addition to many other types of surgery) is associated with both higher morbidity and mortality rates [21,23,24]. In agreement with this literature, the current study also found that the elective or non-elective admission for gastrectomy correlated well with survival. Interestingly, the number of non-elective admissions for both TG and PG peaked at both ends of the age spectrum (youngest and oldest), with the in-

creased number of non-elective admissions in the PG group compared to the TG group perhaps indicative of surgical bias and teaching, which urges performing the least radical procedure necessary in the sick patient.

Published reports of increased medical and surgical complications post gastrectomy among the elderly are numerous, and uniformly comment on decreased complications when performing PG compared to TG—albeit this is not just in the elderly population [22,25,26]. Gastrointestinal (GI) complications (11.3%) were the most common surgical complication noted in the current study (ICD 997.4). Medical complications were noted in 16% of patients, and were far more of a concern in TG patients (23.6%) than PG patients (13.6%). In the TG group, the most common complication overall was respiratory issues (18%) which is similar to the findings of Bittner *et al.* [10]. While Bitner *et al.* did report on variations in complications between gastrectomy patients <70 and >70 years, the current report is the first study to analyze complications by decade. It is quite clear from the current results that the increased morbidity in elderly patients comes primarily in the form of medical complications (namely respiratory and cardiac events) and not surgical complications. (**Tables 6(a)** and **(b)**) Furthermore, cardiac events occurred at nearly twice the rate in the TG (6.1%) compare that PG group (3.2%). Taken on the whole, these results support the notion that when feasible, PG is the preferred surgical therapy in elderly patients (particularly in those with pre-existing co-morbidities that may increase the likelihood of post-operative complications).

The limitations of the study are that it is primarily retrospective in nature, as well as those factors inherent in working with large administrative databases. Complications that may have occurred post-discharge or on readmission within 30 days of procedure were not necessarily captured by the data set. That said, the underestimation of the actual complication rates should apply across all patients equally and thus not alter the findings of this report. In addition, the current study is limited by errors in coding that may have occurred at the time of the hospitalization. Under-reporting of co-morbidities in elderly patients is another potential limitation due to not including confounding factors like frailty, in which three or more of these following criteria are present: unintentional weight loss, exhaustion, weakness, slow walking speed, and low physical activity [27]. Finally, this study did not differentiate between stages of disease or extent of lymphadenectomy performed which could affect outcomes.

In summary, age alone is not an independent factor predictive of increased mortality following gastrectomy, while non-elective admissions, gastric cancer, hyperten-

sion, valvular disease and anemia are. That said, whereas the elderly are more likely to be afflicted with these (and other co-morbidities), as well as to suffer from increased rates of post-operative morbidity, these results imply that surgical risk stratification of patients considered from gastrectomy, should focus primarily on the overall preoperative status of the patient's health rather than their chronologic age. Can gastrectomy be safely performed in elderly patients with acceptable clinical outcomes? The answer is yes. That said, all efforts should be made to optimize the patients remediable pre-operative co-morbidities prior to elective procedures, and provide appropriate counseling regarding the risks and expected postoperative course. Which type of gastrectomy is safer or preferred in the elderly patient remains a more difficult question to answer. While all surgeons have as their mantra "do no harm" and should select the least radical operation with similar outcomes and lowest anticipated morbidity/mortality, these goals must be undertaken against a backdrop of following sound surgical oncologic principles, by achieving a negative margin and adequate information to permit appropriate staging.

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