



# Long-term effects of total vs. partial pancreatectomy among patients with pancreatic cancer: a population-based study

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**Background:** Total pancreatectomy (TP) for pancreatic cancer (PC) has been limited historically for fear of elevated perioperative morbidity and mortality. With advances in perioperative care, TP may be an alternative option to partial pancreatectomy (PP). Limited evidence clarified the indication for these two procedures in PC patients, especially in patients with different tumor staging and location. Thus, this study aims to compare the outcomes after TP and PP for PCs of different T stages and locations.

**Methods:** The study identified 14,456 PC patients with potentially curable primary tumor (T1–3) who received TP or PP from the Surveillance, Epidemiology, and End Results (SEER) database during 2000 to 2016. Detailed clinical and tumor covariates were all collected. Overall survival (OS) and cancer-specific survival (CSS) were the primary endpoints of interest in this study. OS and CSS were compared between patients after TP and PP using log-rank analysis.

**Results:** For all patients, except for tumor location, TP group was comparable to the PP group. OS and CSS of the TP group were worse than of the PP group (median OS: 19 *vs.* 20 months,  $P=0.0058$ ; median CSS: 24 *vs.* 26 months,  $P=0.00098$ , respectively). In stratifying analyses, TP was significantly related to worse OS and CSS than PP in pancreatic head and neck cancer patients with T2-stage tumors (median OS: 18 *vs.* 19 months,  $P=0.0016$ ; median CSS: 22 *vs.* 24 months,  $P=0.00055$ , respectively), whereas for patients with T1- or T3-stage pancreatic head and neck cancer as well as T1- to T3-stage pancreatic body and tail cancer or overlapping location cancer, OS and CSS of the two groups were similar (all  $P>0.05$ ).

**Conclusions:** Compared with PP, TP offered worse prognosis in pancreatic head and neck cancer patients with T2-stage tumors, furthermore, TP and PP achieved comparable prognosis in patients with T1- or T3-stage pancreatic head and neck cancer as well as T1- to T3-stage pancreatic body and tail cancer or overlapping location cancer.

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**Keywords:** Pancreatic cancer (PC); partial pancreatectomy (PP); Surveillance, Epidemiology, and End Results database (SEER database); survival; total pancreatectomy (TP)

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## Introduction

In the USA, pancreatic cancer (PC) ranks 10th in men and 9th in women among all new malignancies, and ranks 4th in malignancy-related mortality (1). As the sole potentially curative therapy, surgical resection is recommended for resectable tumors (2). Partial pancreatectomy (PP), including pancreaticoduodenectomy and distal pancreatectomy, is currently the primary surgical procedure depending on the tumor location. Pancreaticoduodenectomy is the surgery option for tumors of the head and neck, while distal pancreatectomy is applied to tumors of the body and tail (3). In clinical practice, total pancreatectomy (TP) has also been performed to avoid pancreatic fistula after PP depending on the pancreatic texture and risk profile and achieving negative margins to improve survival (4,5). Several indications for this procedure are as follows: large or locally advanced tumors requiring radical resection, multifocal or infiltrating tumors, and PP is technically impractical (6,7). However, the role of TP for PC is still controversial. Several previous studies showed similar overall survival (OS) of PC patients after PP and TP (5,8,9), and other reports presented encouraging results for TP (10,11). Variations in surgical proficiency and perioperative care techniques among surgeons at each center may contribute to this controversial effect. Furthermore, most of the published data on the effect of TP on PC are from single-center retrospective studies with small samples and generally focused on pancreatic head cancer including all T stages (12-14). Therefore, it is necessary to use large-scale, multicenter data to analyze the role of TP for PC of different stages and locations.

The American Joint Committee on Cancer (AJCC) published the 8th edition of TNM staging of PC, which has been used from January 2018 (15). In this edition for T-staging, a tumor size of 4 cm is applied as the cutoff for T2 and T3, which has been reported to be highly prognostic (16). To date, studies of TP for PC have failed to stratify patients according to the new T-stage combined with tumor location. Therefore, the influence of TP on survival of patients with PC at disparate locations and

T-stages remains unclear.

Because PC is relatively rare, the Surveillance, Epidemiology, and End Results (SEER) database is a unique resource that overcomes the challenges of single- or multicenter analyses. We conducted a comparison of OS and cancer-specific survival (CSS) after TP vs. PP in patients with PC at disparate locations and T-stages using a large sample from SEER. We present the following article in accordance with the STROBE reporting checklist (available at <https://atm.amegroups.com/article/view/10.21037/atm-22-2217/rc>).

## Methods

### *Ethics approval*

We retrieved all patient information used in our study from the SEER database, so the institutional review board approval could be waived. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

### *Patients and study design*

The SEER database compiles data on cancer incidence, prevalence and survival of approximately 34.6% of the American population (17). We identified PC patients from 2000 to 2016 using the dedicated software (SEER\*Stat 8.3.9). Patients who met our inclusion criteria were entered into the study: (I) >18 years of age; (II) pathologically confirmed diagnosis of PC, including ductal adenocarcinoma, acinar cell carcinoma, pancreatoblastoma, and solid pseudopapillary neoplasm of pancreases; (III) no evidence of distant metastasis; (IV) potentially curable primary tumor (T1-3); (V) history of partial or TP. Exclusion criteria were: (I) incomplete information in key medical record; (II) tumor located in pancreatic ducts, islets of Langerhans, or unknown location.

We also collected the following patient-related data: age, race, sex, year of diagnosis, tumor location, pathologic grade, number and mode of regional lymph node resection,

tumor size, surgical type, other tumor history, insurance status, marital status, survival status and SEER cause-specific death classification. Patients were divided into TP and PP groups based on the method of pancreatic resection.

The vital status and follow-up information for all patients are updated regularly in each SEER registry. Survival time was calculated based on the time of surgery and the time of death or last follow-up visit. OS and CSS were the primary endpoints of interest in this study. We defined OS as the time between surgery and death from any cause or the last follow-up, and CSS as the time between surgery and death from PC or the last follow-up.

Patients were stratified by tumor location or tumor size. First, we stratified patients into a head and neck subgroup, body and tail subgroup, and overlapping subgroup based on tumor location. Next, patients were subclassified into T1 ( $\leq 2$  cm), T2 ( $\leq 4$  cm) and T3 ( $>4$  cm) subgroups according to tumor size. Finally, we stratified the patients based on tumor location combined with T-stage, resulting in 9 subgroups: head and neck-T1, head and neck-T2, head and neck-T3, body and tail-T1, body and tail-T2, body and tail-T3, overlapping-T1, overlapping-T2 and overlapping-T3.

### Statistical analysis

Comparison of continuous variables was performed with Mann-Whitney U-test or Student's *t*-test. Comparison of categorical variables was conducted with Fisher's exact test or Chi-square test, and comparison of ordinal variables was performed with the Kruskal-Wallis test.  $P \geq 0.05$  were considered comparable when the variables were compared between the two groups. Kaplan-Meier method was used to plot survival curves and the log-rank test was used to compare them. Continuous data were converted into categorical data by optimal cut points selected according to the judgments of clinical experts or clinical reference values. The survival hazard was calculated by a full Cox proportional hazard regression model, which included clinical factors and surgical treatment methods and adopted a forward stepwise procedure. Variables with *P* values less than 0.05 in the full Cox regression analysis were independent predictors of survival. All statistical analyses in this study were performed with R software (<https://www.r-project.org/>; version 4.0.4).  $P < 0.05$  was considered to be statistically significant for all statistical tests and two-sided tests were used to calculate *P* values.

## Results

### All patients

The baseline features of all patients in this study are shown in *Table 1*. In total, we extracted the data for 14,456 PC patients with potentially curable primary tumors (T1–3) from the SEER database, which were allocated to a PP ( $n=12,006$ ) and TP ( $n=2,450$ ) group. For the PP and TP groups, the median follow-up was 70 and 67 months respectively. Compared with pancreatic body and tail cancer, surgeons seemed to be more willing to try TP for pancreatic head and neck cancer. No significant difference was shown in race, sex, age, number and mode of regional lymph node resection, tumor size and tumor pathology grade between groups.

The results of survival analyses revealed that both the OS and CSS of the TP group were significantly worse than those of the PP group (median survival: 19 *vs.* 20 months,  $P=0.0058$ ; median CSS: 24 *vs.* 26 months,  $P=0.00098$ , respectively) (*Figure 1A,1B*). In order to further investigate the association between TP and poorer survival, Cox proportional hazards regression was performed to control for potential confounders. Analyses showed that TP was still the independent risk factor for OS and CSS after adjusting all other variables [OS: hazard ratio (HR), 1.061; 95% confidence interval (CI), 1.010 to 1.114;  $P=0.020$ ; CSS: HR, 1.063; 95% CI, 1.004 to 1.126;  $P=0.036$ ] (*Table 2*).

### Patients stratified by tumor location or tumor size

Patients were stratified by tumor location or tumor size to additionally study the influence of TP on the survival of PC patients with tumors located in different locations or with tumors of different sizes. The clinicopathologic features of patients subclassified based on tumor location are listed in *Table S1*. We stratified patients into a head and neck subgroup, body and tail subgroup, and overlapping subgroup based on tumor location. Variables were distributed relatively uniformly in both the TP and PP groups of all three subgroups. In patients with tumors located in the head and neck of the pancreas, compared with PP, TP was significantly associated with poorer OS and CSS (median OS: 20 *vs.* 18 months,  $P=0.0096$ ; median CSS: 25 *vs.* 23 months,  $P=0.0044$ , respectively; *Figure 2A,2B*). However, in the body and tail subgroup and the overlapping subgroup, the OS and CSS of the TP group resembled

**Table 1** Clinicopathologic characteristics of all patients

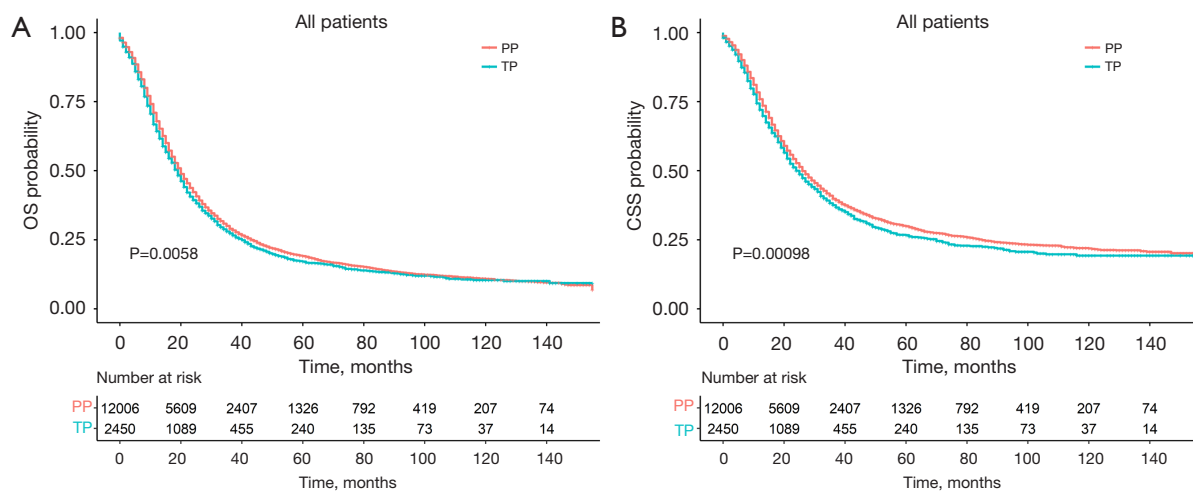
Variables	PP (n=12,006)	TP (n=2,450)	P value
Race, n (%)			0.905
White	9,917 (82.6)	2,027 (82.7)	
Black	1,164 (9.7)	231 (9.4)	
Other	925 (7.7)	192 (7.8)	
Sex, n (%)			0.107
Female	6,007 (50)	1,182 (48.2)	
Male	5,999 (50)	1,268 (51.8)	
Year of diagnosis, n (%)			0.278
2002–2007	3,197 (26.6)	683 (27.9)	
2008–2011	4,205 (35)	866 (35.3)	
2012–2015	4,604 (38.3)	901 (36.8)	
Location of PC, n (%)			<0.001
Head and neck	8,848 (73.7)	1,944 (79.3)	
Body and tail	2,285 (19)	251 (10.2)	
Overlapping	520 (4.3)	118 (4.8)	
Not specified	353 (2.9)	137 (5.6)	
Pathologic grade, n (%)			0.197
I	1,401 (11.7)	285 (11.6)	
II	6,136 (51.1)	1,212 (49.5)	
III	4,263 (35.5)	919 (37.5)	
IV	206 (1.7)	34 (1.4)	
LN resection, n (%)			0.068
0	256 (2.1)	45 (1.8)	
1–3	762 (6.3)	134 (5.5)	
>4	10,832 (90.2)	2,227 (90.9)	
Biopsy	56 (0.5)	20 (0.8)	
Unknown	100 (0.8)	24 (1.0)	
Tumor size (cm), n (%)			0.665
≤2	2,064 (17.2)	403 (16.4)	
≤4	6,855 (57.1)	1,408 (57.5)	
>4	3,087 (25.7)	639 (26.1)	
Other tumor history, n (%)			0.015
No	9,098 (75.8)	1,913 (78.1)	
Yes	2,908 (24.2)	537 (21.9)	

**Table 1** (continued)

Table 1 (continued)

Variables	PP (n=12,006)	TP (n=2,450)	P value
Age (years), n (%)			0.461
≤60	3,352 (27.9)	702 (28.7)	
>60	8,654 (72.1)	1,748 (71.3)	
Age (years), median [IQR]	67 [59, 74]	67 [59, 74]	0.617
Insurance, n (%)			<0.001
Uninsured	196 (1.6)	51 (2.1)	
Insured	8,561 (71.3)	1,718 (70.1)	
Medicaid	874 (7.3)	134 (5.5)	
Unknown	2,375 (19.8)	547 (22.3)	
Marital status, n (%)			0.614
Unmarried	1,326 (11.0)	285 (11.6)	
Married	7,528 (62.7)	1,538 (62.8)	
Other <sup>#</sup>	3,152 (26.3)	627 (25.6)	

<sup>#</sup>, divorced, separated, widowed and unknown. PP, partial pancreatectomy; TP, total pancreatectomy; PC, pancreatic cancer; LN, lymph node; IQR, interquartile range.



**Figure 1** Kaplan-Meier survival curves for all patients undergoing TP or PP. (A) Kaplan-Meier OS and (B) CSS curves for all patients. OS, overall survival; PP, partial pancreatectomy; TP, total pancreatectomy; CSS, cancer-specific survival.

those of the PP group (all  $P > 0.05$ ; *Figure 2C-2F*).

Next, patients were subclassified into T1 ( $\leq 2$  cm), T2 ( $\leq 4$  cm) and T3 ( $> 4$  cm) subgroups according to tumor size. *Table S2* summarizes the features of the patients in the three subgroups. In all subgroups, PC patients with tumors located in the head and neck were more likely to

undergo TP. The results of survival analyses are presented in *Figure 3*. Compared with PP, TP led to a lower OS and CSS of patients with T2-stage tumors (median OS: 20 *vs.* 18 months,  $P = 0.00046$ ; median CSS: 26 *vs.* 23 months,  $P = 0.00027$ , respectively, *Figure 3C, 3D*). However, except for the CSS of patients with T3-stage tumors (median CSS:

**Table 2** Cox regression analyses for OS and CSS in all patients

Variables	OS		CSS	
	HR (95% CI)	P value	HR (95% CI)	P value
Race				
White	Reference		Reference	
Black	1.076 (1.009–1.147)	0.025	1.033 (0.959–1.112)	0.393
Other	0.939 (0.873–1.009)	0.085	0.932 (0.858–1.012)	0.095
Sex				
Female	Reference		Reference	
Male	1.111 (1.069–1.154)	<0.001	1.080 (1.033–1.129)	0.001
Year of diagnosis				
2002–2007	Reference		Reference	
2008–2011	0.911 (0.852–0.974)	0.006	0.887 (0.819–0.960)	0.003
2012–2015	0.830 (0.775–0.890)	<0.001	0.805 (0.742–0.874)	<0.001
Location of PC				
Head and neck	Reference		Reference	
Body and tail	0.838 (0.795–0.883)	<0.001	0.808 (0.758–0.862)	<0.001
Overlapping	0.925 (0.843–1.015)	0.099	1.000 (0.897–1.115)	0.994
Not specified	0.954 (0.859–1.060)	0.382	0.992 (0.877–1.122)	0.899
Pathologic grade				
I	Reference		Reference	
II	1.551 (1.451–1.658)	<0.001	1.646 (1.519–1.784)	<0.001
III	2.063 (1.926–2.209)	<0.001	2.171 (1.999–2.357)	<0.001
IV	1.673 (1.427–1.962)	<0.001	1.884 (1.565–2.268)	<0.001
Pancreatectomy				
Partial	Reference		Reference	
Total	1.061 (1.010–1.114)	0.020	1.063 (1.004–1.126)	0.036
LN resection				
0	Reference		Reference	
1–3	1.008 (0.866–1.172)	0.923	1.029 (0.858–1.234)	0.757
>4	0.924 (0.808–1.057)	0.251	0.997 (0.849–1.170)	0.968
Biopsy	0.885 (0.662–1.183)	0.410	1.006 (0.719–1.407)	0.972
Unknown	0.962 (0.760–1.217)	0.747	1.044 (0.798–1.366)	0.752
Tumor size (cm)				
≤2	Reference		Reference	
≤4	1.406 (1.331–1.484)	<0.001	1.433 (1.344–1.529)	<0.001
>4	1.687 (1.587–1.793)	<0.001	1.685 (1.568–1.811)	<0.001

**Table 2** (continued)

Table 2 (continued)

Variables	OS		CSS	
	HR (95% CI)	P value	HR (95% CI)	P value
Other tumor history				
No	Reference		Reference	
Yes	0.877 (0.838–0.917)	<0.001	0.108 (0.096–0.122)	<0.001
Age (years)				
≤60	Reference		Reference	
>60	1.319 (1.263–1.377)	<0.001	1.239 (1.180–1.300)	<0.001
Insurance				
Uninsured	Reference		Reference	
Insured	1.049 (0.897–1.226)	0.551	0.978 (0.828–1.156)	0.796
Medicaid	1.309 (1.106–1.550)	0.002	1.176 (0.980–1.411)	0.082
Unknown	1.116 (0.943–1.320)	0.203	1.050 (0.875–1.260)	0.598
Marital status				
Unmarried	Reference		Reference	
Married	0.930 (0.874–0.990)	0.023	0.950 (0.884–1.021)	0.165
Other <sup>#</sup>	1.066 (0.995–1.140)	0.068	1.065 (0.985–1.152)	0.116

<sup>#</sup>, divorced, separated, widowed and unknown. OS, overall survival; CSS, cancer-specific survival; PC, pancreatic cancer; LN, lymph node; HR, hazard ratio; CI, confidence interval.

22 vs. 20 months,  $P=0.047$ ), no significant difference of OS and CSS of patients with T1- and OS of patients with T3-stage tumors were observed between groups (all  $P>0.05$ ) (Figure 3A,3B,3E,3F).

#### Patients stratified by combination of tumor location and size

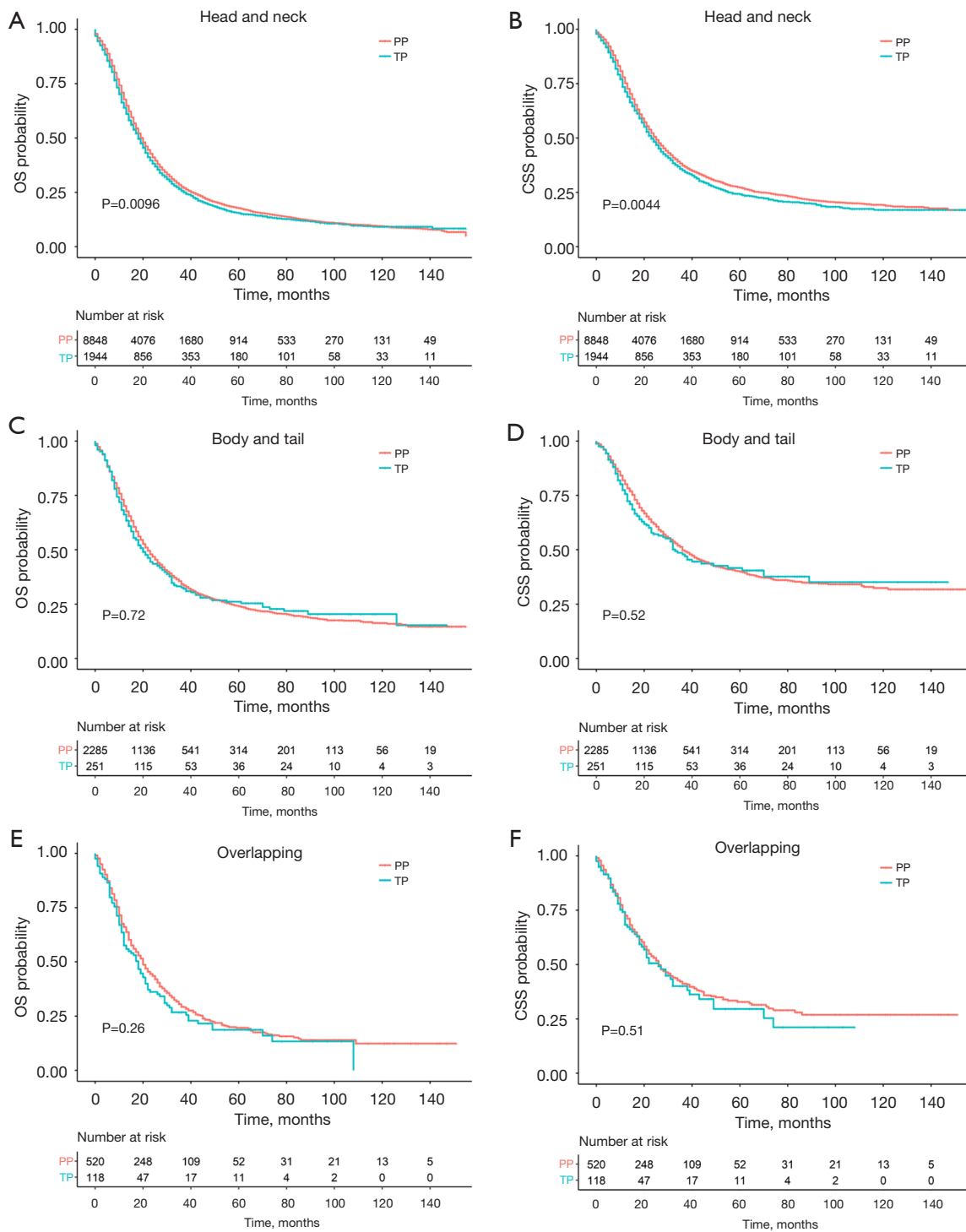
To further investigate the survival effects of TP on pancreatic head and neck cancer, body and tail cancer, and overlapping cancer at different T stages, we stratified the patients based on tumor location combined with T-stage, resulting in 9 subgroups: head and neck-T1, head and neck-T2, head and neck-T3, body and tail-T1, body and tail-T2, body and tail-T3, overlapping-T1, overlapping-T2 and overlapping-T3. The baseline features of the patients in these 9 subgroups were comparable between the TP and PP groups (Tables S3–S5).

There was no significant difference in the OS and CSS between the two groups of patients with T1- and T3-stage tumors (both  $P>0.05$ ) (Figure 4A,4B). Among the

PC patients with T2-stage tumors located in the head and neck of pancreas, the OS and CSS of patients in the TP group were also significantly worse than those of patients in the PP group (median OS: 18 vs. 19 months,  $P=0.0016$ ; median CSS: 22 vs. 24 months,  $P=0.00055$ , respectively) (Figure 4C,4D). The Cox proportional hazards model further demonstrated that TP was independently related to poorer OS and CSS of patients in the head and neck-T2 subgroup (OS: HR, 1.100; 95% CI, 1.027 to 1.179;  $P=0.007$ ; CSS: HR, 1.112; 95% CI, 1.027 to 1.203;  $P=0.009$ ) but not of patients in the other two subgroups (all  $P>0.05$ ) (Table S6). Other independent predictors of OS and CSS, such as pathologic grade, other tumor history and age, are presented in Table S6. There was also no significant difference in the OS and CSS between the two groups of patients with T3-stage tumors (both  $P>0.05$ ) (Figure 4E,4F).

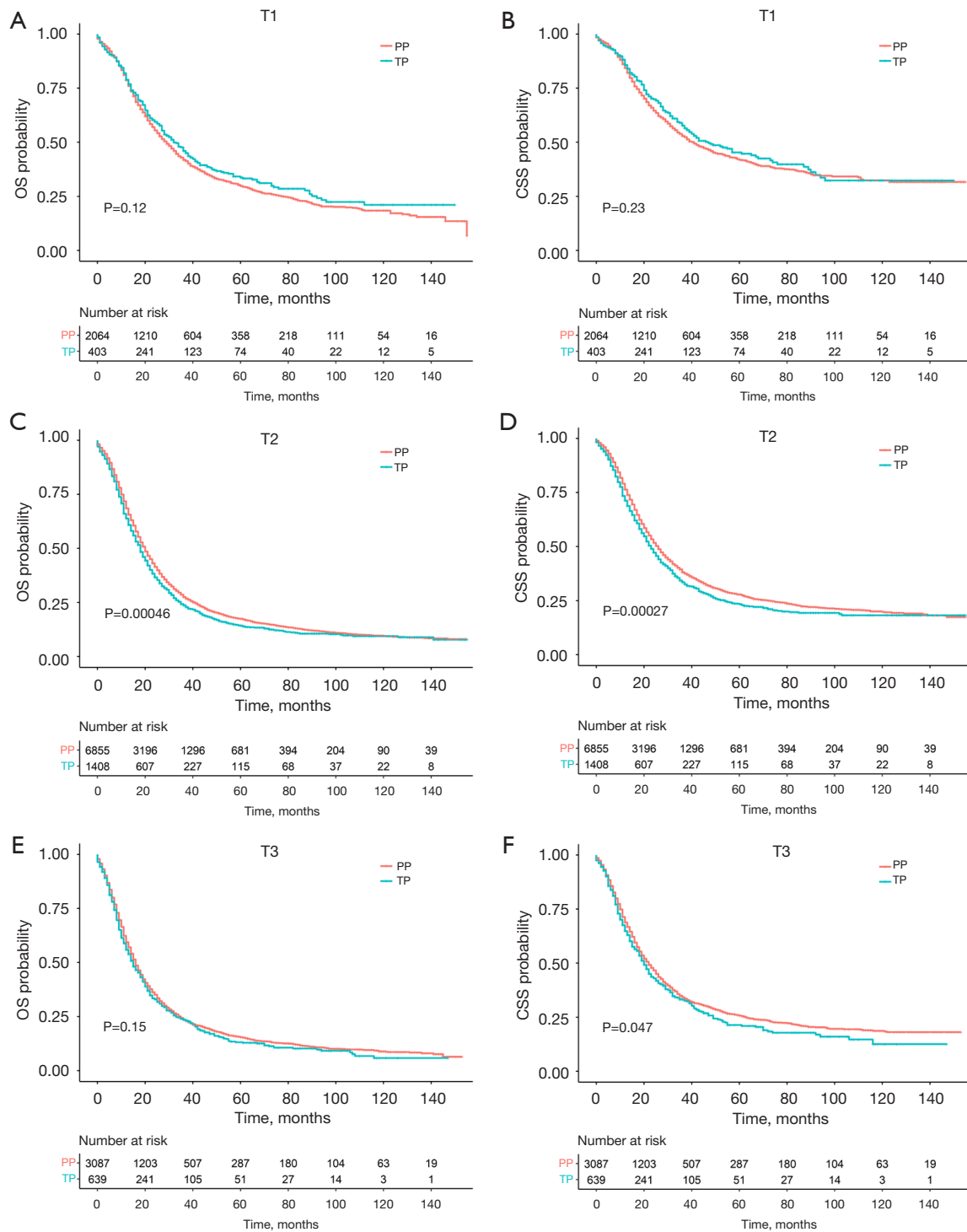
In pancreatic body and tail cancer as well as overlapping cancer, the OS and CSS of patients with all T stages were not significantly different between the TP and PP groups (all  $P>0.05$ ) (Figures S1,S2). The results of the Cox proportional hazards regression analyses of all these



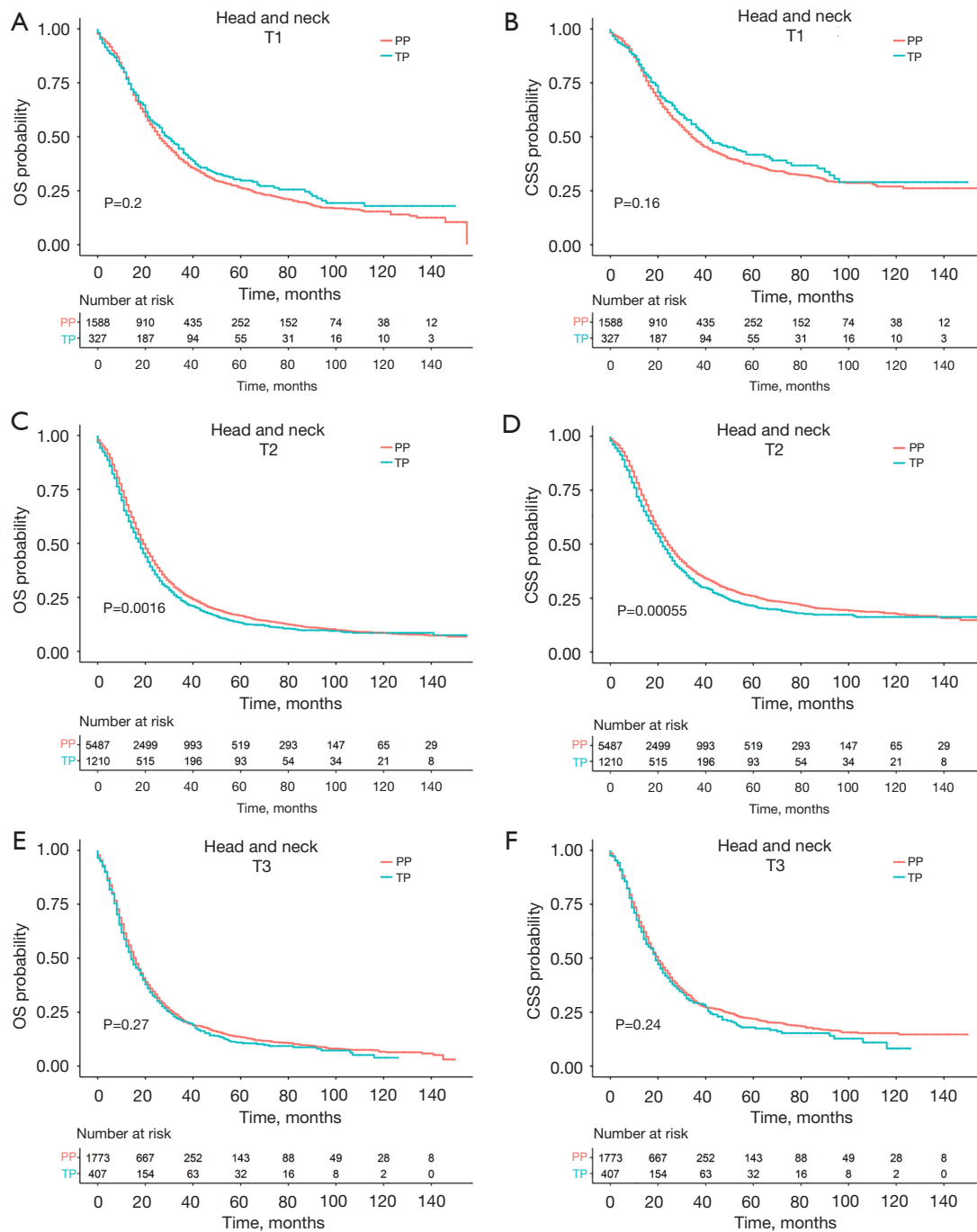


**Figure 2** Kaplan-Meier survival curves for patients undergoing TP or PP stratified by tumor location. OS and CSS for patients with tumors located in the pancreatic head and neck (A,B), body and tail (C,D), and overlapping location (E,F). OS, overall survival; PP, partial pancreatectomy; TP, total pancreatectomy; CSS, cancer-specific survival.





**Figure 3** Kaplan-Meier survival curves for patients undergoing TP or PP stratified by tumor size. OS and CSS for patients with T1-stage tumors (A,B), T2-stage tumors (C,D), and T3-stage tumors (E,F). OS, overall survival; PP, partial pancreatectomy; TP, total pancreatectomy; CSS, cancer-specific survival.



**Figure 4** Kaplan-Meier survival curves for patients undergoing TP or PP stratified by combination of tumor location and size. OS and CSS for pancreatic head and neck cancer patients with T1-stage tumors (A,B), T2-stage tumors (C,D), and T3-stage tumors (E,F). OS, overall survival; PP, partial pancreatectomy; TP, total pancreatectomy; CSS, cancer-specific survival.

subgroups are summarized in Tables S7,S8. TP was not associated with the OS and CSS of patients in any of these subgroups.

## Discussion

TP was initially introduced as a more thorough resection for PC, and was expected to produce better therapeutic effects (18). In the early years, because of the high perioperative morbidity and mortality after TP as well as lifelong diabetes mellitus and exocrine dysfunction, which affected the long-term outcomes and quality of life (QOL) of patients, surgeons preferred PP to TP (19-21). However, with the development of high-volume pancreatic centers, improved surgical techniques, and advances in perioperative care, the perioperative morbidity and mortality for TP have improved substantially (22-24). Furthermore, in recent years, the QOL of patients after TP has remarkably improved due to the wide clinical application of long-acting and medium-acting insulin and modern pancreatin drugs (25-27). Therefore, the appropriateness of TP has been reconsidered and it is being used in an increasing number of patients. Nevertheless, there is an ongoing debate as to whether TP leads to better long-term survival for PC compared with PP.

Using a large sample of data from the SEER database, we demonstrated a significant survival disadvantage for patients with PC after TP compared with PP. Because tumor location and size are significantly associated with PC prognosis (28-31), we further investigated the effect of TP on survival in PC patients with different tumor locations and tumor sizes. A negative effect on long-term prognosis was found for T2-stage pancreatic head and neck cancer after TP compared with PP. Several reasons might be accountable for our results. Firstly, patients in this study were enrolled from 2000 to 2016 and there was no appropriate endocrine therapy for TP patients in the early 2000's which might compromise the survival of patients who received TP. Secondly, the persistently high morbidity of complications associated with TP including total exocrine pancreatic insufficiency and postoperative brittle diabetes could also contribute to the poor survival (30). The diabetes post-TP led to prolonged hospital stay and increase 5-10% mortality rate (32). Finally, clinically relevant information like carbohydrate antigen 19-9 (CA 19-9), body mass index (BMI), comorbidities and chemotherapy, which are associated with survival, are lacking in the SEER database.

A study of 1,386 PC patients compared the effects of

TP (n=100) and pancreaticoduodenectomy (n=1,286) on survival, and concluded that the long-term prognosis of both groups of patients was similar (5). A more recent study revealed that TP with a negative margin was associated with a more favorable survival outcome compared with marginal positive resection with PP; thus, TP was recommended when PP with negative margin was impractical (33). However, our present study showed that both the OS and CSS of the TP group were significantly worse than those of the PP group, and TP was an independent risk factor for OS and CSS. Most of the previous studies were retrospective single-center studies with relatively small sample sizes, whereas our study enrolled a large sample of patients from multiple centers and CSS was one of the primary study endpoints. Therefore, it is reasonable to believe that the results of this study are more reliable. Furthermore, previous studies generally focused on pancreatic head cancer including all T stages, whereas this study looked at potentially curable (AJCC T1-3) PC at all locations. This difference may also lead to differences in research results.

It is appropriate to speculate that the effect of TP is disparate for PC at different anatomical locations. Artinyan *et al.* reported that pancreatic body and tail cancer patients had a shorter median survival, a higher likelihood of distant metastasis, and a lower likelihood of surgical treatment than pancreatic head cancer patients (28). Two other studies verified the differences in both the genes and prognosis between pancreatic body and tail cancer and pancreatic head cancer (34,35). Our subgroup analyses results showed that in patients with tumors located in the head and neck of pancreas, TP was significantly associated with poorer OS and CSS, whereas in the body and tail subgroup and overlapping subgroup, the OS and CSS of the TP group resembled those of the PP group. In a previous study, Passeri *et al.* failed to find differences in survival between patients treated with TP and patients with tumors at different locations treated with PP. Although it stratified the patients undergoing PP according to tumor location, the patients who underwent TP were not stratified in the same way, which affects the credibility of the research results (9).

Tumor size is one of the three key aspects of the TNM staging system for solid tumors and a major predictor of tumor prognosis (36). Results of a study performed by Marchegiani *et al.* revealed different surgical outcomes between pancreatic ductal adenocarcinoma patients with tumor size  $\leq 2$  and  $>2$  cm (37). Another study also found that the survival rate declined with increasing

tumor size in patients with localized pancreatic ductal adenocarcinoma (38). Johnston *et al.* reported that tumor size independently related to survival of PC patients undergoing TP (30). Therefore, stratification of PC according to tumor size is necessary to compare the influence of TP and PP on the survival of PC patients. The newest edition of the TNM staging of PC added tumor size of 4 cm as the cutoff of T2 and T3, which has been reported to be highly prognostic (16,39). Unfortunately, to our knowledge, no studies have been conducted to stratify patients according to this version of T-staging to compare the surgical outcomes of TP and PP. We found that TP led to decreased OS and CSS of patients with T2-stage tumors. In further analyses, we found that for PC patients with T2-stage tumors located in the head and neck of pancreas, the OS and CSS of patients in the TP group were significantly worse than for the PP group. In contrast, the same results were not found in other subgroup analyses.

Several limitations in our study need to be noted. Firstly, we stratified patients into three groups by the tumor size. According to the available information in the SEER database, the tumor size was obtained by measuring either pathologic specimen or pre-operative CT scans. However, the tumor size of measuring the pathologic specimens, the gold standard for determining tumor size, is usually slightly larger than that of measuring the pre-operative CT scans. Hence, it would be better to stratify patients according to tumor size measuring the pathologic specimen in the future study. Secondly, on account of the limited form of information available in the SEER database, information regarding clinical prognosis, such as BMI, CA 19-9 or other diseases, were not available. Therefore, the effect of this information on patient survival could not be studied. Thirdly, pancreatic neck cancer has different clinicopathologic characteristics compared to head or body-tail PC. A previous study reported that patients with pancreatic neck cancer had worse prognosis than patients with head or body-tail PC due to more frequently invading in peripheral major vessels (40). Therefore, it should be better to divide head and neck PC in two different subgroups. Finally, the current study analyses patients underwent TP and PP for all types of PC. Given different types of PC have different prognosis, it should be better to supplement additional analysis to investigate and compare the same data for each type of PC in the future.

## Conclusions

Survival was significantly poorer for patients with potentially curable PC who underwent TP than PP. In terms of different tumor locations and sizes, TP is significantly related to worse survival than PP for T2-stage pancreatic head and neck cancer patients. Further investigations are required to identify independent risk factors associated with the TP treatment.

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## Footnote

*Reporting Checklist:* The authors have completed the STROBE reporting checklist. Available at <https://atm.amegroups.com/article/view/10.21037/atm-22-2217/rc>

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at <https://atm.amegroups.com/article/view/10.21037/atm-22-2217/coif>). The authors have no conflicts of interest to declare.

*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The authors retrieved all patient information used in this study from the SEER database, so the institutional review board approval could be waived. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

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**Table S1** Clinicopathologic characteristics of patients stratified by tumor location

Variables	Head and neck			Body and tail			Overlapping		
	PP (n=8,848)	TP (n=1,944)	P value	PP (n=2,285)	TP (n=2,510)	P value	PP (n=520)	TP (n=118)	P value
Race, n (%)			0.36			0.183			0.564
White	7,375 (83.4)	1,616 (83.1)		1,825 (79.9)	199 (79.3)		425 (81.7)	101 (85.6)	
Black	844 (9.5)	174 (9.0)		240 (10.5)	34 (13.5)		45 (8.7)	9 (7.6)	
Other	629 (7.1)	154 (7.9)		220 (9.6)	18 (7.2)		50 (9.6)	8 (6.8)	
Gender, n (%)			0.347			0.853			0.158
Female	4,328 (48.9)	928 (47.7)		1,243 (54.4)	135 (53.8)		271 (52.1)	53 (44.9)	
Male	4,520 (51.1)	1,016 (52.3)		1,042 (45.6)	116 (46.2)		249 (47.9)	65 (55.1)	
Year of diagnosis, n (%)			0.177			0.507			0.356
2002–2007	2,405 (27.2)	551 (28.3)		547 (23.9)	64 (25.5)		129 (24.8)	34 (28.8)	
2008–2011	3,104 (35.1)	703 (36.2)		786 (34.4)	92 (36.7)		185 (35.6)	34 (28.8)	
2012–2015	3,339 (37.7)	690 (35.5)		952 (41.7)	95 (37.8)		206 (39.6)	50 (42.4)	
Pathology grade, n (%)			0.292			0.88			0.283
I	950 (10.7)	211 (10.9)		333 (14.6)	38 (15.1)		65 (12.5)	16 (13.6)	
II	4,556 (51.5)	956 (49.2)		1,164 (50.9)	132 (52.6)		247 (47.5)	51 (43.2)	
III	3,222 (36.4)	750 (38.6)		729 (31.9)	76 (30.3)		189 (36.3)	50 (42.4)	
IV	120 (1.4)	27 (1.4)		59 (2.6)	5 (2.0)		19 (3.7)	1 (0.8)	
LN resection, n (%)			0.049			0.503			0.569
None	121 (1.4)	30 (1.5)		106 (4.6)	9 (3.6)		11 (2.1)	3 (2.5)	
1–3	452 (5.1)	101 (5.2)		236 (10.3)	20 (8.0)		33 (6.3)	4 (3.4)	
>4	8,165 (92.3)	1,777 (91.4)		1,918 (83.9)	220 (87.6)		470 (90.4)	109 (92.4)	
Biopsy	41 (0.5)	20 (1.0)		10 (0.4)	0 (0.0)		1 (0.2)	0 (0.0)	
Unknown	69 (0.8)	16 (0.8)		15 (0.7)	2 (0.8)		5 (1.0)	2 (1.7)	
Tumor size (cm), n (%)			0.409			0.351			0.297
≤2	1,588 (17.9)	327 (16.8)		339 (14.8)	36 (14.3)		58 (11.2)	8 (6.8)	
≤4	5,487 (62.0)	1,210 (62.2)		996 (43.6)	99 (39.4)		205 (39.4)	45 (38.1)	
>4	1,773 (20.0)	407 (20.9)		950 (41.6)	116 (46.2)		257 (49.4)	65 (55.1)	
Other tumor history, n (%)			0.123			0.069			0.576
No	6,919 (78.2)	1,551 (79.8)		1,537 (67.3)	183 (72.9)		379 (72.9)	83 (70.3)	
Yes	1,929 (21.8)	393 (20.2)		748 (32.7)	68 (27.1)		141 (27.1)	35 (29.7)	
Age (years), n (%)			0.84			0.245			0.597
≤60	2,515 (28.4)	557 (28.7)		587 (25.7)	73 (29.1)		146 (28.1)	36 (30.5)	
>60	6,333 (71.6)	1,387 (71.3)		1,698 (74.3)	178 (70.9)		374 (71.9)	82 (69.5)	
Age (years), median [IQR]	67 [59, 74]	67 [59, 74]	0.769	68 [60, 75]	67 [59, 74.5]	0.124	67 [59, 75]	67 [59.2, 74]	0.557
Insurance, n (%)			0.017			0.007			0.601
Uninsured	156 (1.8)	38 (2.0)		26 (1.1)	8 (3.2)		7 (1.3)	3 (2.5)	
Insured	6,220 (70.3)	1,344 (69.1)		1,717 (75.1)	185 (73.7)		392 (75.4)	83 (70.3)	
Medicaid	669 (7.6)	118 (6.1)		161 (7.0)	9 (3.6)		25 (4.8)	6 (5.1)	
Unknown	1,803 (20.4)	444 (22.8)		381 (16.7)	49 (19.5)		96 (18.5)	26 (22.0)	
Marital status, n (%)			0.738			0.985			0.264
Unmarried	1,001 (11.3)	232 (11.9)		236 (10.3)	26 (10.4)		52 (10.0)	10 (8.5)	
Married	5,542 (62.6)	1,210 (62.2)		1,441 (63.1)	157 (62.5)		334 (64.2)	85 (72)	
Other	2,305 (26.1)	502 (25.8)		608 (26.6)	68 (27.1)		134 (25.8)	23 (19.5)	

LN, lymph node; IQR, interquartile range; PP, partial pancreatectomy; TP, total pancreatectomy.



**Table S2** Clinicopathologic characteristics of patients stratified by tumor size

Variables	T1			T2			T3		
	PP (n=2,064)	TP (n=403)	P value	PP (n=6,855)	TP (n=1,408)	P value	PP (n=3,087)	TP (n=639)	P value
Race, n (%)			0.025			0.607			0.45
White	1,733 (84)	316 (78.4)		5,633 (82.2)	1,170 (83.1)		2,551 (82.6)	541 (84.7)	
Black	173 (8.4)	45 (11.2)		692 (10.1)	130 (9.2)		299 (9.7)	56 (8.8)	
Other	158 (7.7)	42 (10.4)		530 (7.7)	108 (7.7)		237 (7.7)	42 (6.6)	
Gender, n (%)			0.568			0.259			0.326
Female	1,082 (52.4)	205 (50.9)		3,531 (51.5)	702 (49.9)		1,394 (45.2)	275 (43.0)	
Male	982 (47.6)	198 (49.1)		3,324 (48.5)	706 (50.1)		1,693 (54.8)	364 (57.0)	
Year of diagnosis, n (%)			0.211			0.069			0.118
2002–2007	578 (28.0)	110 (27.3)		1,771 (25.8)	392 (27.8)		848 (27.5)	181 (28.3)	
2008–2011	724 (35.1)	159 (39.5)		2,382 (34.7)	506 (35.9)		1,099 (35.6)	201 (31.5)	
2012–2015	762 (36.9)	134 (33.3)		2,702 (39.4)	510 (36.2)		1,140 (36.9)	257 (40.2)	
Location, n (%)			<0.001			<0.001			<0.001
Head and neck	1,588 (76.9)	327 (81.1)		5,487 (80.0)	1,210 (85.9)		1,773 (57.4)	407 (63.7)	
Body and tail	339 (16.4)	36 (8.9)		996 (14.5)	99 (7.0)		950 (30.8)	116 (18.2)	
Overlapping	58 (2.8)	8 (2.0)		205 (3.0)	45 (3.2)		257 (8.3)	65 (10.2)	
Pancreas <sup>a</sup>	79 (3.8)	32 (7.9)		167 (2.4)	54 (3.8)		107 (3.5)	51 (8.0)	
Pathology grade, n (%)			0.519			0.282			0.449
I	373 (18.1)	73 (18.1)		716 (10.4)	142 (10.1)		312 (10.1)	70 (11.0)	
II	1,103 (53.4)	219 (54.3)		3,539 (51.6)	693 (49.2)		1,494 (48.4)	300 (46.9)	
III	559 (27.1)	109 (27.0)		2,521 (36.8)	555 (39.4)		1,183 (38.3)	255 (39.9)	
IV	29 (1.4)	2 (0.5)		79 (1.2)	18 (1.3)		98 (3.2)	14 (2.2)	
LN resection, n (%)			0.371			0.296			0.719
None	55 (2.7)	8 (2.0)		117 (1.7)	23 (1.6)		84 (2.7)	14 (2.2)	
1–3	164 (7.9)	26 (6.5)		400 (5.8)	75 (5.3)		198 (6.4)	33 (5.2)	
>4	1,820 (88.2)	360 (89.3)		6,240 (91.0)	1,282 (91.1)		2,772 (89.8)	585 (91.5)	
Biopsy	10 (0.5)	4 (1.0)		36 (0.5)	14 (1.0)		10 (0.3)	2 (0.3)	
Unknown	15 (0.7)	5 (1.2)		62 (0.9)	14 (1.0)		23 (0.7)	5 (0.8)	
Other tumor history, n (%)			0.313			0.029			0.48
No	1,528 (74)	308 (76.4)		5,214 (76.1)	1,109 (78.8)		2,356 (76.3)	496 (77.6)	
Yes	536 (26)	95 (23.6)		1,641 (23.9)	299 (21.2)		731 (23.7)	143 (22.4)	
Age (years), n (%)			0.725			0.431			0.562
≤60	607 (29.4)	115 (28.5)		1,848 (27.0)	394 (28.0)		897 (29.1)	193 (30.2)	
>60	1,457 (70.6)	288 (71.5)		5,007 (73.0)	1,014 (72.0)		2,190 (70.9)	446 (69.8)	
Age (years), median [IQR]	67 [59, 75]	67 [59, 74]	0.816	67 [60, 75]	68 [59, 75]	0.819	67 [59, 74]	66 [59, 73]	0.139
Insurance, n (%)			0.222			0.002			0.054
Uninsured	35 (1.7)	11 (2.7)		111 (1.6)	22 (1.6)		50 (1.6)	18 (2.8)	
Insured	1,443 (69.9)	288 (71.5)		4,972 (72.5)	986 (70.0)		2,146 (69.5)	444 (69.5)	
Medicaid	153 (7.4)	21 (5.2)		476 (6.9)	76 (5.4)		245 (7.9)	37 (5.8)	
Unknown	433 (21.0)	83 (20.6)		1,296 (18.9)	324 (23.0)		646 (20.9)	140 (21.9)	
Marital status, n (%)			0.918			0.178			0.119
Unmarried	249 (12.1)	47 (11.7)		720 (10.5)	171 (12.1)		357 (11.6)	67 (10.5)	
Married	1,281 (62.1)	248 (61.5)		4,307 (62.8)	861 (61.2)		1,940 (62.8)	429 (67.1)	
Other	534 (25.9)	108 (26.8)		1,828 (26.7)	376 (26.7)		790 (25.6)	143 (22.4)	

<sup>a</sup>, tumor location is not specified. LN, lymph node; IQR, interquartile range; PP, partial pancreatectomy; TP, total pancreatectomy.

**Table S3** Clinicopathologic characteristics of pancreatic head and neck cancer patients stratified by tumor size

Variables	T1			T2			T3		
	PP (n=1,588)	TP (n=327)	P value	PP (n=5,487)	TP (n=1,210)	P value	PP (n=1,773)	TP (n=407)	P value
Race, n (%)			0.1			0.318			0.528
White	1,343 (84.6)	262 (80.1)		4,541 (82.8)	1,003 (82.9)		1,491 (84.1)	351 (86.2)	
Black	137 (8.6)	33 (10.1)		548 (10.0)	108 (8.9)		159 (9.0)	33 (8.1)	
Other	108 (6.8)	32 (9.8)		398 (7.3)	99 (8.2)		123 (6.9)	23 (5.7)	
Gender, n (%)			0.778			0.542			0.538
Female	810 (51.0)	164 (50.2)		2,774 (50.6)	600 (49.6)		744 (42.0)	164 (40.3)	
Male	778 (49.0)	163 (49.8)		2,713 (49.4)	610 (50.4)		1,029 (58.0)	243 (59.7)	
Year of diagnosis, n (%)			0.117			0.059			0.303
2002–2007	465 (29.3)	90 (27.5)		1,446 (26.4)	345 (28.5)		494 (27.9)	116 (28.5)	
2008–2011	566 (35.6)	136 (41.6)		1,912 (34.8)	439 (36.3)		626 (35.3)	128 (31.4)	
2012–2015	557 (35.1)	101 (30.9)		2,129 (38.8)	426 (35.2)		653 (36.8)	163 (40.0)	
Pathology grade, n (%)			0.669			0.306			0.973
I	252 (15.9)	56 (17.1)		528 (9.6)	115 (9.5)		170 (9.6)	40 (9.8)	
II	860 (54.2)	170 (52.0)		2,840 (51.8)	594 (49.1)		856 (48.3)	192 (47.2)	
III	457 (28.8)	99 (30.3)		2,060 (37.5)	485 (40.1)		705 (39.8)	166 (40.8)	
IV	19 (1.2)	2 (0.6)		59 (1.1)	16 (1.3)		42 (2.4)	9 (2.2)	
LN resection, n (%)			0.17			0.166			0.956
None	27 (1.7)	8 (2.4)		61 (1.1)	15 (1.2)		33 (1.9)	7 (1.7)	
1–3	101 (6.4)	24 (7.3)		274 (5.0)	61 (5.0)		77 (4.3)	16 (3.9)	
>4	1,444 (90.9)	288 (88.1)		5,079 (92.6)	1,109 (91.7)		1,642 (92.6)	380 (93.4)	
Biopsy	5 (0.3)	4 (1.2)		29 (0.5)	14 (1.2)		7 (0.4)	2 (0.5)	
Unknown	11 (0.7)	3 (0.9)		44 (0.8)	11 (0.9)		14 (0.8)	2 (0.5)	
Other tumor history, n (%)			0.583			0.058			0.634
No	1,216 (76.6)	255 (78.0)		4,286 (78.1)	975 (80.6)		1,417 (79.9)	321 (78.9)	
Yes	372 (23.4)	72 (22.0)		1,201 (21.9)	235 (19.4)		356 (20.1)	86 (21.1)	
Age (years), n (%)			0.643			0.678			0.879
≤60	472 (29.7)	93 (28.4)		1,514 (27.6)	341 (28.2)		529 (29.8)	123 (30.2)	
>60	1,116 (70.3)	234 (71.6)		3,973 (72.4)	869 (71.8)		1,244 (70.2)	284 (69.8)	
Age (years), median [IQR]	66 [59, 74]	67 [59, 74]	0.491	67 [60, 74]	67 [59, 75]	0.607	66 [59, 73]	65 [59, 72]	0.411
Insurance, n (%)			0.132			0.014			0.633
Uninsured	28 (1.8)	11 (3.4)		94 (1.7)	17 (1.4)		34 (1.9)	10 (2.5)	
Insured	1,083 (68.2)	228 (69.7)		3,933 (71.7)	839 (69.3)		1,204 (67.9)	277 (68.1)	
Medicaid	125 (7.9)	18 (5.5)		388 (7.1)	71 (5.9)		156 (8.8)	29 (7.1)	
Unknown	352 (22.2)	70 (21.4)		1,072 (19.5)	283 (23.4)		379 (21.4)	91 (22.4)	
Marital status, n (%)			0.598			0.258			0.073
Unmarried	195 (12.3)	39 (11.9)		581 (10.6)	146 (12.1)		225 (12.7)	47 (11.5)	
Married	989 (62.3)	196 (59.9)		3,460 (63.1)	739 (61.1)		1,093 (61.6)	275 (67.6)	
Other	404 (25.4)	92 (28.1)		1,446 (26.4)	325 (26.9)		455 (25.7)	85 (20.9)	

LN, lymph node; IQR, interquartile range; PP, partial pancreatectomy; TP, total pancreatectomy.

**Table S4** Clinicopathologic characteristics of pancreatic body and tail cancer patients stratified by tumor size

Variables	T1			T2			T3		
	PP (n=339)	TP (n=36)	P value	PP (n=996)	TP (n=99)	P value	PP (n=950)	TP (n=116)	P value
Race, n (%)			0.135			0.053			0.874
White	276 (81.4)	25 (69.4)		790 (79.3)	79 (79.8)		759 (79.9)	95 (81.9)	
Black	27 (8.0)	6 (16.7)		106 (10.6)	16 (16.2)		107 (11.3)	12 (10.3)	
Other	36 (10.6)	5 (13.9)		100 (10.0)	4 (4.0)		84 (8.8)	9 (7.8)	
Gender, n (%)			0.57			0.206			0.494
Female	200 (59.0)	23 (63.9)		559 (56.1)	49 (49.5)		484 (50.9)	63 (54.3)	
Male	139 (41.0)	13 (36.1)		437 (43.9)	50 (50.5)		466 (49.1)	53 (45.7)	
Year of diagnosis, n (%)			0.666			0.364			0.934
2002–2007	73 (21.5)	10 (27.8)		227 (22.8)	22 (22.2)		247 (26)	32 (27.6)	
2008–2011	115 (33.9)	12 (33.3)		335 (33.6)	40 (40.4)		336 (35.4)	40 (34.5)	
2012–2015	151 (44.5)	14 (38.9)		434 (43.6)	37 (37.4)		367 (38.6)	44 (37.9)	
Pathology grade, n (%)			0.265			0.711			0.924
I	95 (28.0)	8 (22.2)		132 (13.3)	17 (17.2)		106 (11.2)	13 (11.2)	
II	171 (50.4)	24 (66.7)		523 (52.5)	51 (51.5)		470 (49.5)	57 (49.1)	
III	67 (19.8)	4 (11.1)		324 (32.5)	29 (29.3)		338 (35.6)	43 (37.1)	
IV	6 (1.8)	0 (0.0)		17 (1.7)	2 (2.0)		36 (3.8)	3 (2.6)	
LN resection, n (%)			0.033			0.844			0.688
None	22 (6.5)	0 (0.0)		46 (4.6)	6 (6.1)		38 (4)	3 (2.6)	
1–3	42 (12.4)	0 (0.0)		98 (9.8)	10 (10.1)		96 (10.1)	10 (8.6)	
>4	269 (79.4)	36 (100.0)		842 (84.5)	83 (83.8)		807 (84.9)	101 (87.1)	
Biopsy	5 (1.5)	0 (0.0)		3 (0.3)	0 (0.0)		2 (0.2)	0 (0.0)	
Unknown	1 (0.3)	0 (0.0)		7 (0.7)	0 (0.0)		7 (0.7)	2 (1.7)	
Other tumor history, n (%)			0.873			0.247			0.151
No	212 (62.5)	23 (63.9)		657 (66.0)	71 (71.7)		668 (70.3)	89 (76.7)	
Yes	127 (37.5)	13 (36.1)		339 (34.0)	28 (28.3)		282 (29.7)	27 (23.3)	
Age (years), n (%)			0.621			0.975			0.068
≤60	98 (28.9)	9 (25.0)		230 (23.1)	23 (23.2)		259 (27.3)	41 (35.3)	
>60	241 (71.1)	27 (75)		766 (76.9)	76 (76.8)		691 (72.7)	75 (64.7)	
Age (years), median [IQR]	68 [60, 76]	68 [61.5, 76.5]	0.727	69 [61, 76]	69 [61.5, 76]	0.922	68 [60, 75]	64 [56, 72.2]	0.016
Insurance, n (%)			0.825			0.565			0.001
Uninsured	5 (1.5)	0 (0.0)		11 (1.1)	2 (2.0)		10 (1.1)	6 (5.2)	
Insured	265 (78.2)	27 (75.0)		768 (77.1)	75 (75.8)		684 (72.0)	83 (71.6)	
Medicaid	20 (5.9)	2 (5.6)		65 (6.5)	4 (4.0)		76 (8.0)	3 (2.6)	
Unknown	49 (14.5)	7 (19.4)		152 (15.3)	18 (18.2)		180 (18.9)	24 (20.7)	
Marital status, n (%)			0.794			0.494			0.404
Unmarried	42 (12.4)	5 (13.9)		94 (9.4)	13 (13.1)		100 (10.5)	8 (6.9)	
Married	204 (60.2)	23 (63.9)		625 (62.8)	59 (59.6)		612 (64.4)	75 (64.7)	
Other	93 (27.4)	8 (22.2)		277 (27.8)	27 (27.3)		238 (25.1)	33 (28.4)	

LN, lymph node; IQR, interquartile range; PP, partial pancreatectomy; TP, total pancreatectomy.

**Table S5** Clinicopathologic characteristics of pancreatic overlapping location cancer patients stratified by tumor size

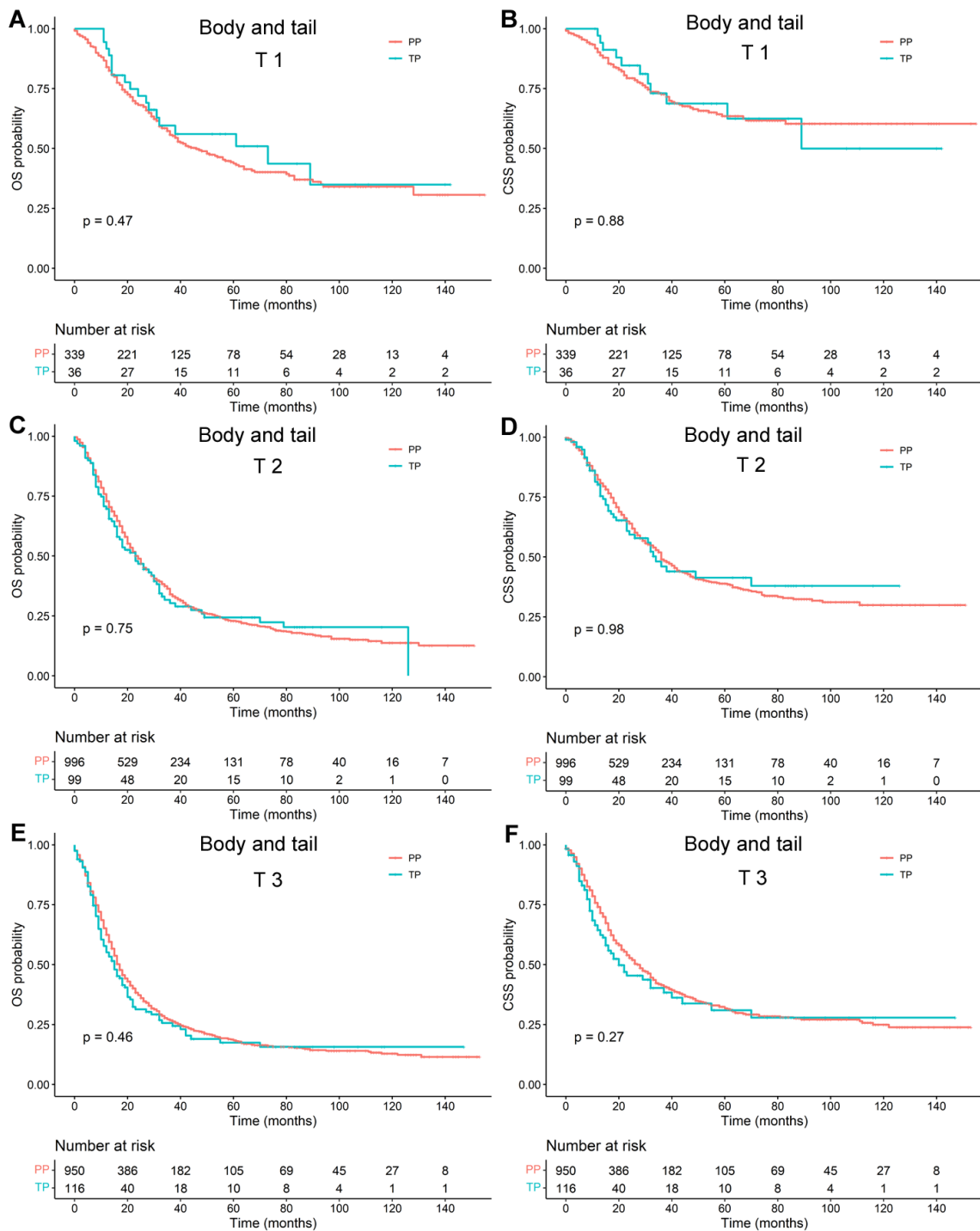
Variables	T1			T2			T3		
	PP (n=58)	TP (n=8)	P value	PP (n=205)	TP (n=45)	P value	PP (n=257)	TP (n=65)	P value
Race, n (%)			0.174			0.115			0.66
White	47 (81.0)	5 (62.5)		162 (79)	41 (91.1)		216 (84.0)	55 (84.6)	
Black	3 (5.2)	2 (25.0)		19 (9.3)	3 (6.7)		23 (8.9)	4 (6.2)	
Other	8 (13.8)	1 (12.5)		24 (11.7)	1 (2.2)		18 (7.0)	6 (9.2)	
Gender, n (%)			0.125			0.669			0.491
Female	35 (60.3)	2 (25.0)		121 (59.0)	25 (55.6)		115 (44.7)	26 (40.0)	
Male	23 (39.7)	6 (75.0)		84 (41.0)	20 (44.4)		142 (55.3)	39 (60.0)	
Year of diagnosis, n (%)			0.127			0.591			0.197
2002–2007	12 (20.7)	0 (0.0)		45 (22.0)	12 (26.7)		72 (28.0)	22 (33.8)	
2008–2011	17 (29.3)	5 (62.5)		70 (34.1)	12 (26.7)		98 (38.1)	17 (26.2)	
2012–2015	29 (50.0)	3 (37.5)		90 (43.9)	21 (46.7)		87 (33.9)	26 (40.0)	
Pathology grade, n (%)			0.252			0.438			0.506
I	10 (17.2)	4 (50)		30 (14.6)	4 (8.9)		25 (9.7)	8 (12.3)	
II	33 (56.9)	3 (37.5)		98 (47.8)	19 (42.2)		116 (45.1)	29 (44.6)	
III	12 (20.7)	1 (12.5)		76 (37.1)	22 (48.9)		101 (39.3)	27 (41.5)	
IV	3 (5.2)	0 (0.0)		1 (0.5)	0 (0.0)		15 (5.8)	1 (1.5)	
LN resection, n (%)			1			0.847			0.326
None	2 (3.4)	0 (0.0)		5 (2.4)	1 (2.2)		4 (1.6)	2 (3.1)	
1–3	6 (10.3)	1 (12.5)		11 (5.4)	1 (2.2)		16 (6.2)	2 (3.1)	
>4	49 (84.5)	7 (87.5)		185 (90.2)	42 (93.3)		236 (91.8)	60 (92.3)	
Biopsy	0 (0.0)	0 (0.0)		1 (0.5)	0 (0.0)		0 (0.0)	0 (0.0)	
Unknown	1 (1.7)	0 (0.0)		3 (1.5)	1 (2.2)		1 (0.4)	1 (1.5)	
Other tumor history, n (%)			0.673			0.307			0.718
No	43 (74.1)	5 (62.5)		152 (74.1)	30 (66.7)		184 (71.6)	48 (73.8)	
Yes	15 (25.9)	3 (37.5)		53 (25.9)	15 (33.3)		73 (28.4)	17 (26.2)	
Age (years), n (%)			0.669			0.406			0.748
≤60	16 (27.6)	1 (12.5)		60 (29.3)	16 (35.6)		70 (27.2)	19 (29.2)	
>60	42 (72.4)	7 (87.5)		145 (70.7)	29 (64.4)		187 (72.8)	46 (70.8)	
Age (years), mean (SD)/median [IQR]	67.8 (11.3)	64.4 (7.2)	0.411	66 (10.3)	65.2 (10.8)	0.634	68 [59, 75]	68 [60, 74]	0.816
Insurance, n (%)			0.606			0.105			0.411
Uninsured	0 (0.0)	0 (0.0)		2 (1.0)	2 (4.4)		5 (1.9)	1 (1.5)	
Insured	45 (77.6)	6 (75.0)		157 (76.6)	32 (71.1)		190 (73.9)	45 (69.2)	
Medicaid	3 (5.2)	1 (12.5)		16 (7.8)	1 (2.2)		6 (2.3)	4 (6.2)	
Unknown	10 (17.2)	1 (12.5)		30 (14.6)	10 (22.2)		56 (21.8)	15 (23.1)	
Marital status, n (%)			0.757			0.447			0.653
Unmarried	8 (13.8)	1 (12.5)		21 (10.2)	5 (11.1)		23 (8.9)	4 (6.2)	
Married	33 (56.9)	6 (75.0)		129 (62.9)	32 (71.1)		172 (66.9)	47 (72.3)	
Other	17 (29.3)	1 (12.5)		55 (26.8)	8 (17.8)		62 (24.1)	14 (21.5)	

LN, lymph node; SD, standard deviation; IQR, interquartile range; PP, partial pancreatectomy; TP, total pancreatectomy.

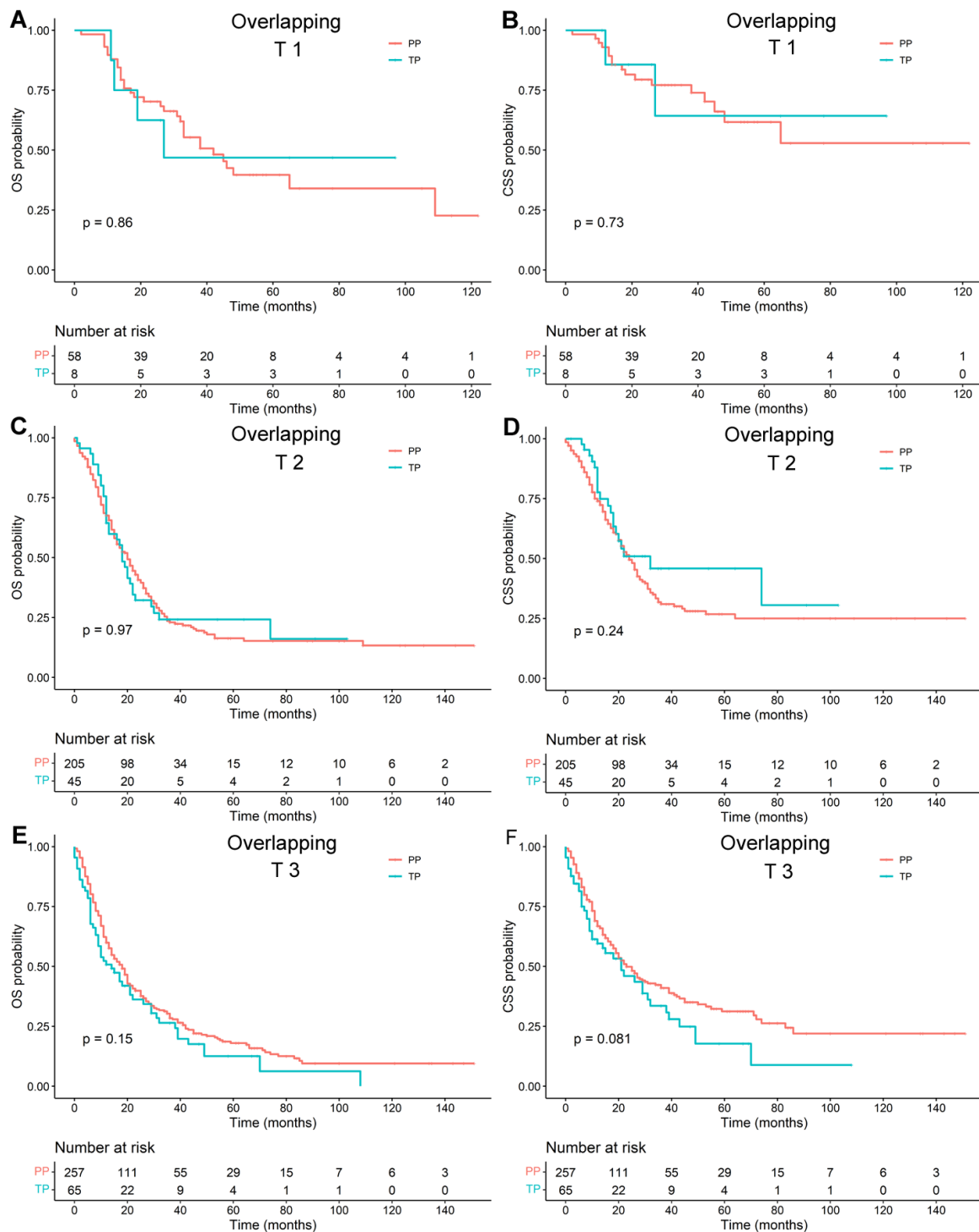
**Table S6** Cox regression analyses for OS and CSS in pancreatic head and neck cancer patients stratified by tumor size

Variables	T1				T2				T3			
	OS		CSS		OS		CSS		OS		CSS	
	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value
<b>Race</b>												
White	Reference		Reference		Reference		Reference		Reference		Reference	
Black	1.126 (0.927–1.368)	0.232	1.130 (0.905–1.411)	0.282	1.082 (0.987–1.185)	0.093	1.020 (0.918–1.134)	0.709	0.945 (0.798–1.118)	0.508	0.935 (0.770–1.134)	0.494
Other	1.109 (0.904–1.360)	0.321	1.176 (0.938–1.474)	0.159	0.931 (0.836–1.037)	0.193	0.913 (0.808–1.031)	0.143	0.913 (0.756–1.102)	0.344	0.913 (0.734–1.135)	0.414
<b>Gender</b>												
Female	Reference		Reference		Reference		Reference		Reference		Reference	
Male	0.989 (0.885–1.106)	0.850	0.983 (0.863–1.118)	0.789	1.135 (1.074–1.200)	<0.001	1.089 (1.021–1.161)	0.009	1.145 (1.039–1.262)	0.006	1.153 (1.032–1.288)	0.012
<b>Year of diagnosis</b>												
2002–2007	Reference		Reference		Reference		Reference		Reference		Reference	
2008–2011	0.881 (0.730–1.064)	0.189	0.780 (0.629–0.968)	0.024	0.924 (0.836–1.021)	0.120	0.915 (0.815–1.027)	0.132	0.942 (0.797–1.113)	0.481	0.987 (0.810–1.203)	0.896
2012–2015	0.731 (0.596–0.896)	0.003	0.658 (0.522–0.831)	<0.001	0.867 (0.782–0.961)	0.007	0.841 (0.747–0.947)	0.004	0.854 (0.719–1.015)	0.073	0.911 (0.743–1.117)	0.369
<b>Pathology grade</b>												
I	Reference		Reference		Reference		Reference		Reference		Reference	
II	1.571 (1.331–1.854)	<0.001	1.630 (1.336–1.988)	<0.001	1.405 (1.270–1.555)	<0.001	1.470 (1.306–1.654)	<0.001	1.493 (1.251–1.780)	<0.001	1.656 (1.335–2.053)	<0.001
III	2.040 (1.708–2.438)	<0.001	2.003 (1.624–2.472)	<0.001	1.838 (1.658–2.039)	<0.001	1.902 (1.686–2.145)	<0.001	1.991 (1.665–2.379)	<0.001	2.278 (1.835–2.829)	<0.001
IV	1.629 (0.969–2.740)	0.066	1.998 (1.066–3.745)	0.031	1.788 (1.362–2.348)	<0.001	1.900 (1.402–2.575)	<0.001	1.748 (1.226–2.491)	0.002	2.569 (1.714–3.851)	<0.001
<b>Pancreatectomy</b>												
Partial	Reference		Reference		Reference		Reference		Reference		Reference	
Total	0.914 (0.789–1.058)	0.227	0.868 (0.730–1.031)	0.106	1.100 (1.027–1.179)	0.007	1.112 (1.027–1.203)	0.009	1.098 (0.977–1.234)	0.118	1.131 (0.990–1.293)	0.071
<b>LN resection</b>												
None	Reference		Reference		Reference		Reference		Reference		Reference	
1–3	0.624 (0.412–0.945)	0.026	0.731 (0.455–1.174)	0.195	0.873 (0.661–1.154)	0.340	0.853 (0.620–1.175)	0.330	1.215 (0.812–1.817)	0.344	1.212 (0.762–1.929)	0.417
>4	0.592 (0.411–0.854)	0.005	0.661 (0.439–0.996)	0.048	0.767 (0.594–0.990)	0.042	0.772 (0.577–1.034)	0.082	0.979 (0.695–1.379)	0.903	1.140 (0.777–1.674)	0.503
Biopsy	0.560 (0.232–1.352)	0.197	0.778 (0.295–2.050)	0.611	0.785 (0.516–1.193)	0.257	0.943 (0.591–1.505)	0.806	0.815 (0.359–1.850)	0.624	0.499 (0.150–1.656)	0.256
Unknown	0.473 (0.230–0.970)	0.041	0.508 (0.235–1.097)	0.085	0.847 (0.576–1.244)	0.397	0.868 (0.562–1.340)	0.523	0.867 (0.464–1.621)	0.655	0.820 (0.395–1.700)	0.594
<b>Other tumor history</b>												
No	Reference		Reference		Reference		Reference		Reference		Reference	
Yes	0.903 (0.793–1.029)	0.126	0.138 (0.102–0.186)	<0.001	0.854 (0.800–0.913)	<0.001	0.110 (0.093–0.131)	<0.001	0.939 (0.837–1.055)	0.290	0.116 (0.085–0.157)	<0.001
<b>Age (years)</b>												
≤60	Reference		Reference		Reference		Reference		Reference		Reference	
>60	1.260 (1.114–1.424)	<0.001	1.189 (1.035–1.365)	0.014	1.276 (1.199–1.359)	<0.001	1.199 (1.119–1.285)	<0.001	1.379 (1.242–1.531)	<0.001	1.304 (1.162–1.462)	<0.001
<b>Insurance</b>												
Uninsured	Reference		Reference		Reference		Reference		Reference		Reference	
Insured	0.986 (0.630–1.545)	0.951	0.946 (0.587–1.522)	0.818	1.012 (0.811–1.263)	0.917	0.909 (0.718–1.151)	0.429	0.996 (0.695–1.429)	0.984	1.012 (0.687–1.490)	0.953
Medicaid	1.195 (0.738–1.937)	0.469	1.014 (0.602–1.707)	0.959	1.307 (1.027–1.663)	0.029	1.124 (0.868–1.457)	0.375	1.227 (0.832–1.809)	0.302	1.273 (0.836–1.937)	0.261
Unknown	1.100 (0.678–1.786)	0.699	0.941 (0.559–1.584)	0.820	1.109 (0.871–1.412)	0.401	1.010 (0.779–1.310)	0.940	0.958 (0.648–1.416)	0.828	1.090 (0.712–1.668)	0.693
<b>Marital status</b>												
Unmarried	Reference		Reference		Reference		Reference		Reference		Reference	
Married	1.026 (0.861–1.224)	0.772	1.138 (0.928–1.396)	0.215	0.900 (0.822–0.986)	0.023	0.929 (0.838–1.030)	0.162	0.932 (0.802–1.082)	0.353	0.990 (0.834–1.176)	0.909
Other	1.045 (0.861–1.269)	0.655	1.108 (0.883–1.390)	0.375	1.042 (0.944–1.150)	0.412	1.057 (0.945–1.183)	0.331	1.076 (0.912–1.268)	0.385	1.125 (0.930–1.361)	0.224

OS, overall survival; CSS, cancer-specific survival; LN, lymph node; HR, hazard ratio; CI, confidence interval.



**Figure S1** Kaplan-Meier survival curves for patients undergoing TP or PP stratified by combining tumor location and size. OS and CSS for pancreatic body and tail cancer patients with T1-stage tumors (A,B), T2-stage tumors (C,D), and T3-stage tumors (E,F). OS, overall survival; PP, partial pancreatectomy; TP, total pancreatectomy; CSS, cancer-specific survival.



**Figure S2** Kaplan-Meier survival curves for patients undergoing TP or PP stratified by combining tumor location and size. OS and CSS for pancreatic overlapping location cancer patients with T1-stage tumors (A,B), T2-stage tumors (C,D), and T3-stage tumors (E,F). OS, overall survival; PP, partial pancreatectomy; TP, total pancreatectomy; CSS, cancer-specific survival.



**Table S7** Cox regression analyses for OS and CSS in pancreatic body and tail cancer patients stratified by tumor size

Variables	T1				T2				T3			
	OS		CSS		OS		CSS		OS		CSS	
	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value
<b>Race</b>												
White	Reference		Reference		Reference		Reference		Reference		Reference	
Black	0.802 (0.465–1.385)	0.429	0.827 (0.418–1.634)	0.584	1.049 (0.827–1.330)	0.694	0.920 (0.682–1.241)	0.585	1.221 (0.978–1.525)	0.078	1.151 (0.886–1.497)	0.292
Other	0.849 (0.514–1.403)	0.524	0.664 (0.338–1.305)	0.235	0.943 (0.737–1.207)	0.643	0.905 (0.680–1.203)	0.492	0.898 (0.695–1.159)	0.408	0.964 (0.706–1.316)	0.817
<b>Gender</b>												
Female	Reference		Reference		Reference		Reference		Reference		Reference	
Male	1.161 (0.865–1.558)	0.321	1.125 (0.743–1.704)	0.577	0.993 (0.859–1.149)	0.927	0.951 (0.791–1.143)	0.589	1.223 (1.062–1.407)	0.005	1.140 (0.960–1.355)	0.136
<b>Year of diagnosis</b>												
2002–2007	Reference		Reference		Reference		Reference		Reference		Reference	
2008–2011	0.689 (0.424–1.120)	0.133	0.370 (0.187–0.733)	0.004	0.907 (0.709–1.160)	0.437	0.979 (0.721–1.329)	0.891	1.206 (0.931–1.564)	0.157	1.232 (0.879–1.727)	0.226
2012–2015	0.707 (0.429–1.166)	0.175	0.452 (0.230–0.887)	0.021	0.921 (0.714–1.186)	0.522	0.933 (0.682–1.277)	0.666	0.924 (0.709–1.203)	0.556	0.999 (0.706–1.414)	0.997
<b>Pathology grade</b>												
I	Reference		Reference		Reference		Reference		Reference		Reference	
II	1.416 (0.987–2.031)	0.059	1.931 (1.130–3.297)	0.016	1.842 (1.444–2.351)	<0.001	2.406 (1.725–3.356)	<0.001	2.458 (1.860–3.249)	<0.001	2.491 (1.778–3.491)	<0.001
III	1.745 (1.122–2.712)	0.013	2.416 (1.304–4.474)	0.005	2.501 (1.936–3.231)	<0.001	3.439 (2.429–4.869)	<0.001	3.230 (2.427–4.299)	<0.001	3.393 (2.395–4.807)	<0.001
IV	0.810 (0.192–3.411)	0.774	3.465 (0.760–15.797)	0.108	2.096 (1.179–3.726)	0.012	1.441 (0.562–3.695)	0.448	1.792 (1.133–2.835)	0.013	1.792 (1.054–3.047)	0.031
<b>Pancreatectomy</b>												
Partial	Reference		Reference		Reference		Reference		Reference		Reference	
Total	0.797 (0.483–1.313)	0.372	1.012 (0.522–1.965)	0.971	1.128 (0.881–1.445)	0.338	1.014 (0.741–1.388)	0.930	1.170 (0.934–1.465)	0.173	1.165 (0.889–1.526)	0.268
<b>LN resection</b>												
None	Reference		Reference		Reference		Reference		Reference		Reference	
1–3	0.679 (0.333–1.385)	0.288	0.674 (0.275–1.654)	0.389	0.890 (0.598–1.326)	0.567	0.863 (0.496–1.501)	0.603	1.362 (0.873–2.125)	0.173	1.231 (0.732–2.072)	0.433
>4	0.872 (0.483–1.574)	0.650	0.762 (0.369–1.574)	0.463	1.016 (0.722–1.430)	0.928	1.136 (0.712–1.813)	0.591	1.156 (0.776–1.724)	0.476	1.191 (0.752–1.886)	0.456
Biopsy	0.290 (0.037–2.272)	0.239	0.281 (0.034–2.334)	0.240	1.170 (0.353–3.881)	0.797	2.907 (0.644–13.114)	0.165	3.969 (0.926–17.013)	0.063	5.166 (1.176–22.691)	0.030
Unknown	0.750 (0.094–6.006)	0.786	3.924e–08 (0–Inf)	0.997	1.181 (0.493–2.829)	0.709	0.981 (0.286–3.360)	0.976	1.642 (0.761–3.544)	0.206	1.583 (0.657–3.815)	0.306
<b>Other tumor history</b>												
No	Reference		Reference		Reference		Reference		Reference		Reference	
Yes	0.962 (0.709–1.305)	0.802	0.064 (0.025–0.159)	<0.001	0.897 (0.771–1.043)	0.158	0.084 (0.055–0.129)	<0.001	1.013 (0.870–1.179)	0.871	0.087 (0.056–0.136)	<0.001
<b>Age (years)</b>												
≤60	Reference		Reference		Reference		Reference		Reference		Reference	
>60	1.414 (0.984–2.030)	0.061	1.372 (0.857–2.196)	0.187	1.351 (1.127–1.618)	0.001	1.201 (0.970–1.487)	0.094	1.363 (1.155–1.608)	<0.001	1.261 (1.042–1.526)	0.017
<b>Insurance</b>												
Uninsured	Reference		Reference		Reference		Reference		Reference		Reference	
Insured	7.309e+06 (0–Inf)	0.992	8.176e+06 (0–Inf)	0.995	0.914 (0.446–1.873)	0.805	0.808 (0.372–1.756)	0.591	1.474 (0.755–2.879)	0.256	1.401 (0.686–2.859)	0.355
Medicaid	1.212e+07 (0–Inf)	0.992	2.059e+07 (0–Inf)	0.994	1.051 (0.492–2.249)	0.897	1.038 (0.453–2.380)	0.929	1.712 (0.841–3.485)	0.139	1.444 (0.665–3.135)	0.353
Unknown	5.717e+06 (0–Inf)	0.992	5.612e+06 (0–Inf)	0.995	1.164 (0.544–2.491)	0.695	1.116 (0.486–2.562)	0.796	1.660 (0.813–3.387)	0.164	1.818 (0.832–3.972)	0.134
<b>Marital status</b>												
Unmarried	Reference		Reference		Reference		Reference		Reference		Reference	
Married	1.082 (0.667–1.753)	0.750	0.766 (0.398–1.473)	0.424	1.066 (0.812–1.398)	0.647	0.956 (0.688–1.328)	0.788	0.992 (0.778–1.264)	0.946	0.915 (0.689–1.215)	0.540
Other	1.398 (0.836–2.337)	0.201	0.931 (0.452–1.914)	0.845	1.243 (0.932–1.657)	0.139	1.112 (0.783–1.579)	0.552	1.089 (0.839–1.414)	0.520	0.902 (0.660–1.232)	0.516

OS, overall survival; CSS, cancer-specific survival; LN, lymph node; HR, hazard ratio; CI, confidence interval.

**Table S8** Cox regression analyses for OS and CSS in pancreatic overlapping location cancer patients stratified by tumor size

Variables	T1				T2				T3			
	OS		CSS		OS		CSS		OS		CSS	
	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value
Race												
White	Reference		Reference		Reference		Reference		Reference		Reference	
Black	1.625 (0.378–6.992)	0.514	1.374 (0.128–14.789)	0.793	1.443 (0.857–2.431)	0.168	1.228 (0.649–2.322)	0.528	1.116 (0.686–1.813)	0.659	1.077 (0.627–1.847)	0.789
Other	1.821 (0.464–7.150)	0.390	2.770 (0.363–21.121)	0.326	1.029 (0.628–1.685)	0.911	1.101 (0.621–1.953)	0.741	0.789 (0.467–1.331)	0.374	0.769 (0.430–1.377)	0.377
Gender												
Female	Reference		Reference		Reference		Reference		Reference		Reference	
Male	1.263 (0.549–2.908)	0.583	0.732 (0.214–2.503)	0.619	0.937 (0.686–1.278)	0.679	0.909 (0.622–1.328)	0.622	1.001 (0.766–1.307)	0.996	0.893 (0.651–1.225)	0.482
Year of diagnosis												
2002–2007	Reference		Reference		Reference		Reference		Reference		Reference	
2008–2011	1.683 (0.338–8.373)	0.525	0.535 (0.070–4.076)	0.546	0.711 (0.395–1.281)	0.256	0.602 (0.294–1.234)	0.166	0.591 (0.374–0.935)	0.025	0.460 (0.269–0.785)	0.004
2012–2015	1.041 (0.198–5.469)	0.963	0.360 (0.039–3.358)	0.370	0.547 (0.305–0.982)	0.043	0.464 (0.229–0.940)	0.033	0.653 (0.407–1.047)	0.077	0.535 (0.309–0.928)	0.026
Pathology grade												
I	Reference		Reference		Reference		Reference		Reference		Reference	
II	4.122 (0.993–17.114)	0.051	5.315 (0.406–69.542)	0.203	1.623 (0.984–2.676)	0.058	1.968 (1.097–3.529)	0.023	1.163 (0.743–1.820)	0.510	1.116 (0.654–1.904)	0.687
III	6.297 (1.214–32.662)	0.029	4.291 (0.311–59.283)	0.277	2.009 (1.200–3.362)	0.008	2.108 (1.158–3.836)	0.015	1.806 (1.146–2.847)	0.011	1.728 (1.013–2.949)	0.045
IV	6.977 (0.810–60.064)	0.077	6.390e-08 (0–Inf)	0.999	3.229 (0.411–25.396)	0.265	3.405 (0.421–27.561)	0.251	1.495 (0.744–3.002)	0.259	1.963 (0.905–4.256)	0.088
Pancreatectomy												
Partial	Reference		Reference		Reference		Reference		Reference		Reference	
Total	1.176 (0.260–5.326)	0.834	2.483 (0.272–22.681)	0.420	1.070 (0.723–1.583)	0.735	0.747 (0.452–1.235)	0.255	1.101 (0.802–1.511)	0.551	1.140 (0.791–1.644)	0.481
LN resection												
None	Reference		Reference		Reference		Reference		Reference		Reference	
1–3	2.138 (0.158–28.838)	0.567	1.138e+09 (0–Inf)	0.999	0.874 (0.279–2.733)	0.817	0.448 (0.073–2.745)	0.385	0.999 (0.282–3.548)	0.999	1.156 (0.244–5.488)	0.855
>4	1.017 (0.091–11.306)	0.989	4.556e+08 (0–Inf)	0.999	0.762 (0.304–1.911)	0.562	1.037 (0.242–4.445)	0.961	1.399 (0.438–4.471)	0.571	1.482 (0.354–6.210)	0.590
Biopsy	NA	NA	NA	NA	1.363 (0.136–13.682)	0.793	1.742 (0.126–24.0950)	0.679	NA	NA	NA	NA
Unknown	1.297e-07 (0–Inf)	0.998	2.557 (0–Inf)	1.000	0.600 (0.137–2.616)	0.496	1.391 (0.216–8.982)	0.728	7.547 (1.127–50.559)	0.037	6.759 (0.841–54.293)	0.072
Other tumor history												
No	Reference		Reference		Reference		Reference		Reference		Reference	
Yes	1.322 (0.580–3.009)	0.507	2.518e-09 (0–Inf)	0.998	0.544 (0.379–0.781)	0.001	0.063 (0.025–0.158)	<0.001	0.622 (0.465–0.832)	0.001	0.102 (0.055–0.189)	<0.001
Age (years)												
≤60	Reference		Reference		Reference		Reference		Reference		Reference	
>60	1.202 (0.458–3.153)	0.708	0.588 (0.184–1.876)	0.370	1.474 (1.050–2.069)	0.025	1.510 (1.034–2.204)	0.033	1.485 (1.095–2.012)	0.011	1.417 (1.005–1.999)	0.047
Insurance												
Uninsured	Reference		Reference		Reference		Reference		Reference		Reference	
Insured	0.455 (0.079–2.623)	0.378	0.551 (0.070–4.340)	0.571	5.666 (0.763–42.055)	0.090	9.661e+06 (0–Inf)	0.995	1.567 (0.617–3.981)	0.345	2.005 (0.707–5.681)	0.191
Medicaid	1.297 (0.156–10.782)	0.810	0.529 (0.021–13.419)	0.700	8.085 (1.012–64.573)	0.049	1.315e+07 (0–Inf)	0.995	1.373 (0.417–4.515)	0.602	1.881 (0.520–6.805)	0.336
Unknown	NA	NA	NA	NA	3.878 (0.501–30.022)	0.194	8.284e+06 (0–Inf)	0.995	1.330 (0.478–3.701)	0.584	1.205 (0.380–3.820)	0.751
Marital status												
Unmarried	Reference		Reference		Reference		Reference		Reference		Reference	
Married	0.586 (0.159–2.158)	0.422	0.433 (0.099–1.903)	0.268	1.092 (0.655–1.820)	0.735	1.270 (0.674–2.393)	0.460	0.557 (0.350–0.886)	0.014	0.571 (0.334–0.974)	0.040
Other	0.661 (0.170–2.564)	0.550	0.399 (0.059–2.681)	0.345	0.959 (0.536–1.717)	0.888	0.980 (0.464–2.068)	0.957	0.852 (0.514–1.413)	0.534	0.923 (0.518–1.643)	0.784

OS, overall survival; CSS, cancer-specific survival; LN, lymph node; HR, hazard ratio; CI, confidence interval; NA, not available.