Conditional survival rate estimates of lobectomy, segmentectomy and wedge resection for stage IA1 non-small cell lung cancer: A population-based study

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Abstract. Conditional survival rate (CSR) is defined as the dynamic possibility of survival, considering the changes in the survival risk over time. The present study aimed to compare the CSR of the surgical procedures for stage IA1 non-small cell lung cancer (NSCLC). Overall, data for 2,535 patients with stage IA1 NSCLC after lobectomy, segmentectomy or wedge resection were obtained from the Surveillance, Epidemiology and End Results database, and the overall survival (OS) rates were subsequently compared. CSR estimates, the possibility of patients who had already survived x years, to survive further y years, was calculated as $CSR=S(x+y)/S(x)$, where S is the survival rate at a particular point in time. A Cox regression model and propensity-score matching were used to adjust confounding factors. There were no statistical differences in the OS among the three surgical procedures, except that OS of patients who underwent a lobectomy was improved compared with the wedge resection. The CSR of surviving to the 5th year after operation improved gradually over time. The 3-year CSR of lobectomy or segmentectomy was higher compared with that of the wedge resection. Moreover, the 3-year CSR of segmentectomy was higher compared with that of lobectomy from the 3rd year after surgery, particularly in some specific situations, such as female sex, patients ≥66 years old, patients with squamous cell carcinoma or patients with poor tumor differentiation. The present study is the first report to compare CSR following lobectomy, segmentectomy and wedge resection for patients with stage IA1 NSCLC, to the best of our knowledge. These findings indicated that lobectomy is the most conservative surgical procedure for stage IA1 NSCLC and raises questions regarding improved long-term prognosis of segmentectomy in some subsets of patients.

Introduction

Despite considerable progresses in the early diagnosis of early-stage lung cancer, the morbidity rate of early-stage non-small cell lung cancer (NSCLC) continues to increase (1). Since 1995, lobectomy remains the preferred option for the resection of early-stage NSCLC (2). However, advances in clinical staging modalities, surgical techniques and preoperative localization techniques have led to a resurgence of interest in sublobar resection for early-stage lung cancer.

In the absence of randomized data, clinical decisions for the increasing number of patients with early-stage NSCLC are intended to smaller extent of resection to avoid treatment-related injuries. Therefore, there is some disagreement regarding whether sublobar resection is the appropriate surgical procedure for early-stage NSCLC (3-5). Concerning stage I NSCLC, retrospective studies have reported similar long-term survival for both sublobar resection and lobectomy but a higher incidence of postoperative recurrence for sublobar resection (6-11). Notably, early-stage NSCLC with tumor sizes ≤1 cm, defined as stage IA1 NSCLC according to the 8th American Joint Committee on Cancer (AJCC)/International Union Against Cancer (IUCC) non-small cell lung cancer staging system, sublobar resection preserves pulmonary function, lowers perioperative morbidity and improves long-term survival quality (12-14).

Tumor size ≤1 cm is the smallest unit of tumor (T) classification according to the 8th AJCC/IUCC non-small cell lung cancer staging system. With increasing tumor sizes, surgeons prefer to perform lobectomies. Therefore, there is a need to study the suitability of sublobar resection in stage IA1 NSCLC. Several previous studies have used cumulative survival when estimating long-term prognosis for patients with stage IA1 NSCLC after different surgical procedures (3,15,16). However, cumulative survival can only provide static survival statistics, which is limited when estimating long-term survival, as the risk of death changes over time (17). In contrast to cumulative survival, the conditional survival rate (CSR) describes the dynamic possibility of survival, considering the changes in the survival risk caused by the increasing longevity (18,19).

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The present study compared the CSR of patients with stage IA1 NSCLC, who had undergone lobectomy, segmentectomy and wedge resection, by utilizing the updated Surveillance, Epidemiology, and End Results Program (SEER) database. A Cox regression model and propensity-score matching (PSM) was used to adjust for confounding factors among the three surgical procedures. The present study may provide new insights into the long-term dynamic survival rate of the three surgical procedures for stage IA1 NSCLC. These results may help inform clinical decision making and provide current dynamic prognostic information.

Patients and methods

Patients. The data were obtained from the SEER database, a population-based cancer database covering above a quarter of the U.S. population (20). In total, 2,535 eligible patients with stage IA1 NSCLC were included in the present study, 1,631 of whom were women and 904 were men. Tumor-Node-Metastasis (TNM) classification was defined by the 8th edition AJCC/UICC NSCLC staging system according to the tumor size (SEER field: CSTUMSIZ) and tumor stage information in SEER (14). All patients who possessed single primary stage IA1 NSCLC, and had undergone lobectomy (SEER codes 30 to 33), segmentectomy (SEER code 22) or wedge resection (SEER code 21) between January 2004 and December 2015 were included in the present study. The exclusion criteria were as follows: i) No diagnosis confirmation microscopically; ii) received chemotherapy or radiotherapy before, during, or after the operation; iii) unknown radiation status; and iv) patients who were lost during follow-up. Fig. 1 shows the flow chart of screening. The baseline characteristics of the patients included surgical procedures, age at diagnosis, sex, ethnicity, histology, tumor sites, differentiation grade, lateral and survival time. Approval from an Institutional Review Board was not required for the present study as SEER is a publicly available database.

Statistical analysis. Student's t-tests were used for comparing continuous variables. χ^2 tests were performed to analyze the difference between categorical variables. Overall survival (OS) rate was calculated based on the SEER fields 'Survival months' and 'Vital Status recode'. Kaplan-Meier analysis and the Renji test were used to compare the differences in OS between surgical procedures. CSR, the possibility of patients surviving further y years, who had already survived for x years, was calculated by CSR (y|x)=S(x+y)/S(x); where S is the OS at a particular point in time (17). For instance, the possibility of the patients who had survived one year after operation remaining alive for an additional three years was expressed as CSR (3|1), which is equivalent to the OS in the fourth year divided by that in the first year.

Competing prognostic factors were adjusted using univariate and multivariate Cox regression analyses. After that, the CSR of the three surgical procedures was estimated among factors independently associated with prognosis in the multivariate analysis. In addition, propensity score matching (PSM) was applied to minimize the potential bias caused by the existing non-randomized assignment analysis data set (21). In each PSM analysis, patients in matched groups
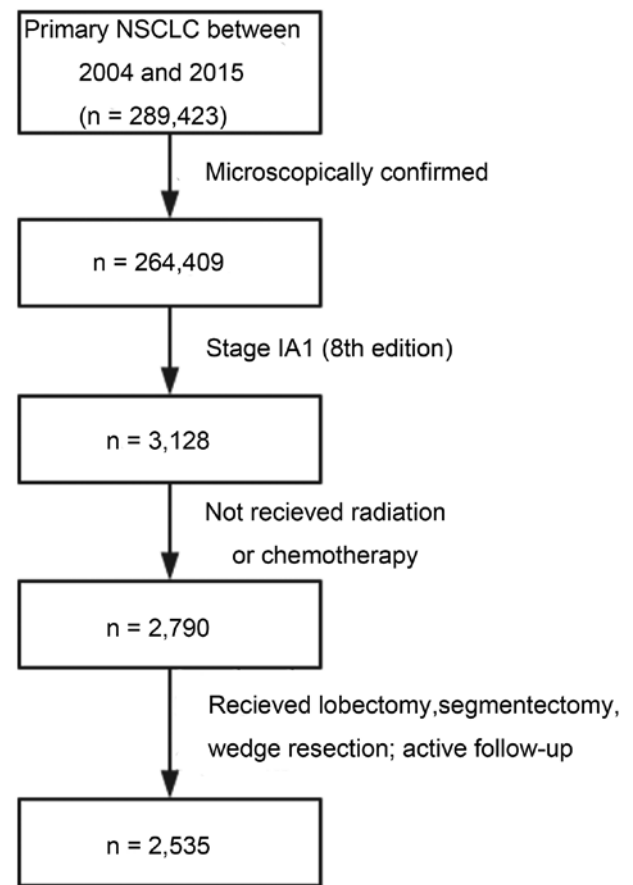

Figure 1. Flow chart for generation of the patient cohort dataset. NSCLC, non-small cell lung cancer.

were matched 1:1 using a logistic model and nearest-neighbor matching method with caliper value of PSM=0.005 (21,22). Furthermore, stratification analyses were performed for the CSR of the surgical procedures, according to the clinicopathological characteristics independently associated with OS.

All the analyses were performed using SPSS version 23.0 (IBM Corp) or R program version 3.2.2 [R Foundation for Statistical Computing; (23)]. P<0.05 was considered to indicate a statistically significant difference.

Results

Clinicopathological characteristics. Out of the 2,535 patients, 1,509 (59.5%), 175 (6.9%), 851 (33.6%) had undergone lobectomy, segmentectomy and wedge resection, respectively. The median age was 67 years (IQR, 59-73 years), and the median tumor size was 0.9 cm (IQR, 0.8-1.0 cm). The clinicopathological characteristics of these patients are summarized in Table I. Accordingly, the largest proportion of the patients had undergone lobectomy. Moreover, lobectomy was more likely to be performed in younger patients, tumors located in the middle lobe, the right lateral and tumors of definite grade. There were insignificant differences in the distribution of three surgical procedures among the ethnicity, sex and histological type (all P>0.05; Table I).

Comparison of OS between the three surgical procedures. Using the Kaplan-Meier method and Renji test, there were

Table I. Clinical characteristics of 2,325 patients with different surgical procedures.

Clinicopathological characteristic	Lobectomy n=1,509 (%)	Segmentectomy n=175 (%)	Wedge resection n=851 (%)	n	χ^2	P-value
Age, years					35.022	<0.001[a]
≤65	748 (65.21)	60 (5.23)	339 (29.56)	1,147		
66-74	525 (56.94)	73 (7.92)	324 (35.14)	922		
≥75	236 (50.64)	42 (9.02)	188 (40.34)	466		
Ethnicity					2.124	0.346
Other	196 (58.51)	18 (5.37)	121 (36.12)	335		
White	1,313 (59.68)	157 (7.14)	730 (33.18)	2,200		
Sex					2.207	0.332
Female	971 (59.53)	104 (6.38)	556 (34.09)	1,631		
Male	538 (59.51)	71 (7.85)	295 (32.63)	904		
Site in lung					12.259	0.016[a]
Lower lobe	445 (58.55)	64 (8.42)	251 (33.03)	760		
Middle lobe	126 (66.32)	3 (1.58)	61 (32.10)	190		
Upper lobe	938 (59.18)	108 (6.81)	539 (34.01)	1,585		
Laterality					19.336	<0.001[a]
Right	962 (62.06)	83 (5.35)	505 (32.59)	1,550		
Left	547 (55.53)	92 (9.34)	346 (35.13)	985		
Histology					1.732	0.785
AD	1,056 (59.26)	129 (7.24)	597 (33.50)	1,782		
SC	257 (59.35)	25 (5.77)	151 (34.88)	433		
Other	196 (61.25)	21 (6.56)	103 (32.19)	320		
Grade					21.366	0.002[a]
I	500 (58.69)	54 (6.34)	298 (34.97)	852		
II	554 (63.17)	71 (8.10)	252 (28.73)	877		
III-IV	276 (59.87)	26 (5.64)	159 (34.49)	461		
Undetermined	179 (51.88)	24 (6.96)	142 (41.16)	345		

[a]P<0.05. AD, adenocarcinoma; SC, squamous cell carcinoma.

no significant differences in the OS between the lobectomy vs. segmentectomy and segmentectomy vs. wedge resection (all P>0.05; Fig. 2A). The 5-year overall survival rate of lobectomy, segmentectomy and wedge resection were 80.4, 75.5 and 70.6%, respectively. However, the OS of lobectomy was superior to that of wedge resection (P<0.001, Fig. 2A). The association between surgical procedures and clinicopathological characteristics was further analyzed using the Cox regression analysis. Significant prognostic factors in the univariate analysis were used in the multivariate analysis. Consequently, it was demonstrated that ethnicity, surgical procedure, sex, age, grade and histology were significantly associated with OS rate (Tables II and III).

Comparison of CSR for the three surgical procedures. The CSR of each year to the fifth year increased gradually over time (Fig. 2B). Taking lobectomy as example, the CSR (5|0), CSR (4|1), CSR (3|2), CSR (2|3), CSR (1|4) and CSR (0|5) were 80.4, 84.5, 88.1, 91.7, 96.3 and 100%, respectively. CSR (2|3)=91.7% implied that 91.7% of the patients who underwent lobectomy and were alive in the 3rd year would also survive

for the next two years. CSR was higher in the lobectomy arm and always lowest in the wedge resection arm. Initially, the CSR in the segmentectomy group was lower compared with that in the lobectomy group but almost equivalent in the last three years. Furthermore, the 3-year CSR changed over time. For instance, 3-year CSR of wedge resection decreased to 0 on the 3rd year, then, it increased gradually (Fig. 2C).

Most of the time, among the three surgical procedures, the 3-year CSR in the lobectomy and segmentectomy groups were superior to that of the wedge resection group. The 3-year CSR in the segmentectomy arm exceeded that of the lobectomy group in the later period (Fig. 2C). PSM was used for pairwise matched surgical procedures to minimize potential bias. When matching, the patients' potential confounding baseline characteristics associated with prognosis, including age (as a continuous variable), sex, histological type and grade, were paired. The baseline characteristics of paired cohorts after PSM were well-balanced (all P>0.05; Tables IV-VI). There was no significant difference in the OS between lobectomy and segmentectomy or between segmentectomy and wedge resection (Fig. 3A-C).
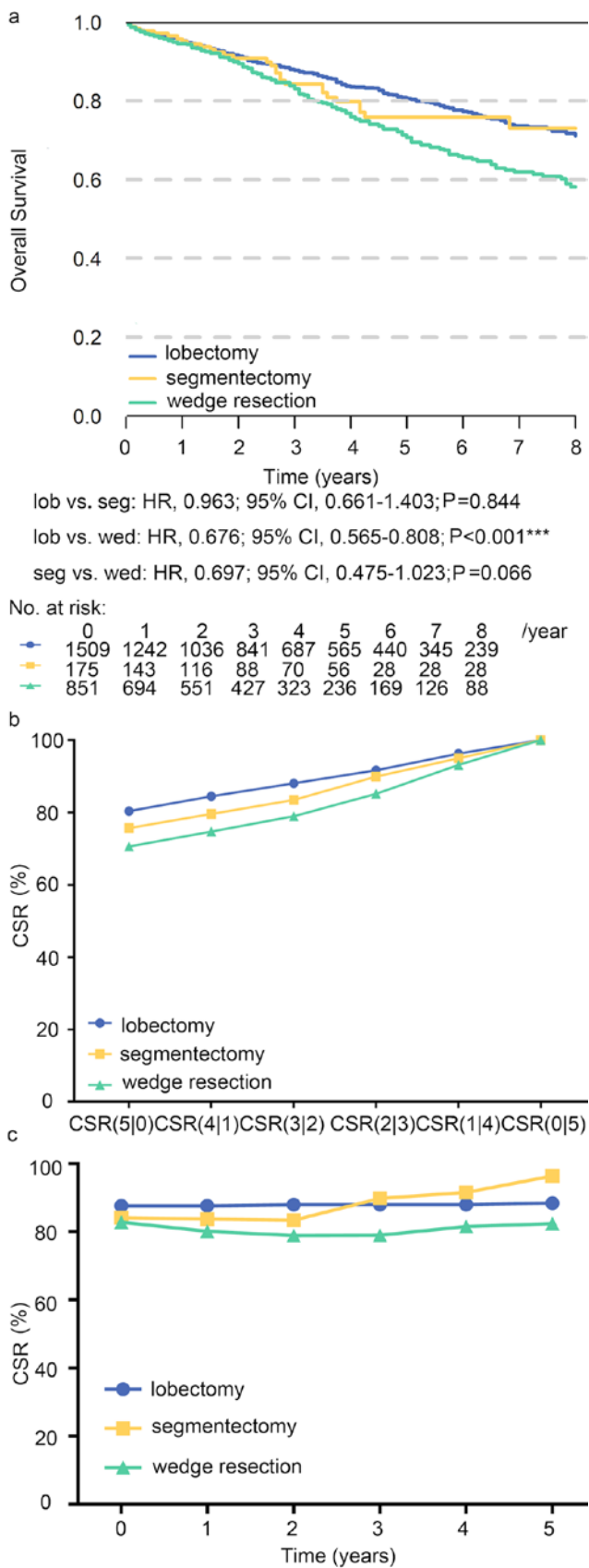
Figure 2. Comparison of overall survival and CSR between the three surgical procedures. (A) Kaplan-Meier survival curve of overall survival after lobectomy, segmentectomy and wedge resection. (B) Changes in CSR(5|0), CSR(4|1), CSR(3|2), CSR(2|3), CSR(1|4) and CSR(0|5). CSR is defined as the probability of surviving to 5th postoperative years after a specific time. (C) Changes in 3-year CSR. 3-year CSR is defined as the probability of surviving to the next 3 years after a specific time. CSR, conditional survival rate; HR, hazard ratio; CI, confidence interval.

Table II. Univariate Cox proportional hazard regression model for patients with stage IA1 non-small cell lung cancer.

Variables	HR	95% CI	P-value
Ethnicity			0.027[a]
White	Reference	-	-
Other	0.712	0.528-0.962	0.027[a]
Sex			<0.001[b]
Male	Reference	-	-
Female	0.607	0.511-0.721	<0.001[b]
Age, years			<0.001[b]
≥75	Reference	-	-
66-74	0.537	0.437-0.661	<0.001[b]
≤65	0.329	0.265-0.409	<0.001[b]
Sites in lung			0.061
Upper	Reference	-	-
Middle	0.621	0.414-0.932	0.021[a]
Lower	0.917	0.755-1.114	0.384
Laterality			0.926
Left	Reference	-	-
Right	1.008	0.846-1.202	0.926
Histology			<0.001[b]
AD	Reference	-	-
SC	2.064	1.693-2.516	<0.001[b]
Other	1.606	1.256-2.053	<0.001[b]
Grade			<0.001[b]
I	Reference	-	-
II	2.109	1.651-2.694	<0.001[b]
III-IV	2.621	2.022-3.396	<0.001[b]
Undetermined	1.942	1.434-2.630	<0.001[b]
Surgical procedure			<0.001[b]
Wedge resection	Reference	-	-
Segmentectomy	0.703	0.479-1.031	0.071
Lobectomy	0.677	0.566-0.811	<0.001[b]

[a]$P<0.05$, [b]$P<0.001$. HR, hazard ratio; CI, confidence interval; AD, adenocarcinoma; SC, squamous cell carcinoma.

However, the OS in the lobectomy group was significantly higher compared with the wedge resection group. The CSR in the lobectomy arm was higher compared with that of the segmentectomy group in the early period; however, the trend reversed in the later period. The CSR in both the lobectomy and segmentectomy groups were higher compared with the wedge resection group (Fig. 4A-C).

The 3-year CSR following stratification analyses is shown in Figs. 5 and 6. In each subgroup analysis, the CSR of the segmentectomy and lobectomy groups were very close but overall higher compared with that of the wedge resection group. Among the patients aged <65-years, the CSR rates of the segmentectomy and the lobectomy groups were almost equal. Regarding age increase, the CSR was lower in the segmentectomy group compared with the lobectomy group in the early period, but the trend reversed in the later period.

Table III. Multivariate cox regression analysis for patients with stage IA1 non-small cell lung cancer.

Variables	HR	95% CI	P value
Race			0.163
White	Reference	-	-
Other	0.807	0.597-1.091	0.163
Sex			<0.001[c]
Male	Reference	-	-
Female	0.636	0.534-0.758	<0.001[c]
Age, years			<0.001[c]
≥75	Reference	-	-
66-74	0.558	0.452-0.688	<0.001[c]
≤65	0.366	0.292-0.457	<0.001[c]
Histology			0.012[a]
AD	Reference	-	-
SC	1.369	1.099-1.704	0.005[b]
Other	1.280	0.988-1.658	0.062
Grade			<0.001[c]
I	Reference	-	-
I	1.827	1.416-2.357	<0.001[c]
III-IV	1.942	1.463-2.577	<0.001[c]
Undetermined	1.815	1.338-2.461	<0.001[c]
Surgical procedure			0.003[b]
Wedge resection	Reference	-	-
Segmentectomy	0.704	0.48-1.034	0.073
Lobectomy	0.737	0.615-0.883	0.001[b]

[a]P<0.05, [b]P<0.01, [c]P<0.001. HR, hazard ratio; CI, confidence interval; AD, adenocarcinoma; SC, squamous cell carcinoma.

There was no statistical difference in the CSR between the three surgical procedure groups in Grade I. The higher the grade, the lower CSR in the segmentectomy group compared with lobectomy arm in the early period. The CSR in female patients in the segmentectomy group was lower compared with that in the lobectomy group in the early period, but the pattern reversed in the late period. However, in male patients, the CSR rate in the lobectomy group was higher compared with the segmentectomy or wedge resection groups. In the adenocarcinoma patient-group, the CSR in the lobectomy group was also higher compared with the segmentectomy or wedge resection groups (Fig. 5B). However, in patients with the squamous cell carcinoma and other types, CSR was lower in the segmentectomy compared with in the lobectomy arm in the first two years; but this trend reversed after two years of operation (Fig. 5D and F).

Discussion

The increasing incidence rate of early-stage NSCLC has led to conflicting arguments regarding the most effective surgical procedure, particularly for small tumors, such as T1a. In the present study, it was reported that that the 5-year overall survival rates for patients with stage IA1 NSCLC, who underwent different surgical procedures, varies from 70-80%, which is consistent with findings from previous studies (3,15). Further, lobectomy is superior to wedge resection surgical procedure in terms of OS (24,25), which is consistent with the present findings. Previous studies indicated that the effectiveness of sublobar resection and lobectomy are equivalent for stage IA1 NSCLC (5,6,26). However, these studies estimated the long-term prognosis of patients with stage IA1 NSCLC using cumulative survival rate, without taking into account the postoperative follow-up information. However, the mortality risk after surgery is dynamic throughout the course of follow-up (27). Therefore, cumulative survival cannot provide accurate estimates of long-term prognosis for oncologists and patients, particularly when patients survive extra years. Compared with cumulative survival, the CSR method reflects the changes in survival probability as the duration of follow-up increases, and is therefore useful in predicting prognosis.

In the present study, it was found that CSR increases as survival time is prolonged overall. This could be due to the elapse of time, and there is a natural selection effect on the initial population as patients with the highest risk of death would die earlier, therefore over time a healthier population remains. However, CSR may decrease during this particular period. To explain this phenomenon, it was assumed that the cumulative survival rate of patients are a, b, c, d, e, f, g, h and i in 0 to the 8th year, which could imply, $a \geq b \geq c \geq d \geq e \geq f \geq g \geq h \geq i$. According to the calculation of the CSR, CSR (3|0)=d/a, CSR(3|1)=e/b and so forth. For example, regarding the CSR curve between years 0-1, when the curve raises, CSR (3|1)-CSR (3|0)=e/b -d/a=(ae-bd)/ ab>0, namely b/a<e/d. This implies that the difference between b and a is larger than the difference between e and d, suggesting that the mortality risk in the later 3 years is lower compared with the first 2 years, demonstrating an improved long-term prognosis after the given time point. When curve slopes downwards, the long-term prognosis after that time point worsens. When curve remains steady, it implies that the death risk is almost equal in first 4 years. This is because the long-term prognosis after this time point gets worse compared with the short-term prognosis near this time point. Based on the derivation, it was reported that the death risk in lobectomy procedure stabilized over time. This implied that lobectomy is the most conservative and appropriate surgical option in stage IA1 NSCLC. However, with the elapse of time, the CSR of segmentectomy arm exceeded that of the lobectomy procedure, suggesting better long-term prognosis of segmentectomy.

CSR can be used to more accurately describe the current prognosis for patients who have survived several years after the surgery. Based on the results of the present study, patients could only be told the expected 5-year survival rate calculated from post-lobectomy was 80.4%. However, this survival rate may be inaccurate, considering the 5-year cumulative survival estimate from the postoperation does not consider the extra survival time. Calculating the CSR (3|2) appropriately addresses this issue. For example, the lobectomy CSR (3|2) was 88.1%, 7.7% higher compared with the OS in the 5th year (80.4%).

In the present study, the CSR (5|0), CSR (4|1), CSR (3|2), CSR (2|3), CSR (1|4) and CSR (0|5) that are the possibilities of surviving to 5th year after each postoperative year, revealed stepwise improvement in all the surgical procedure groups.
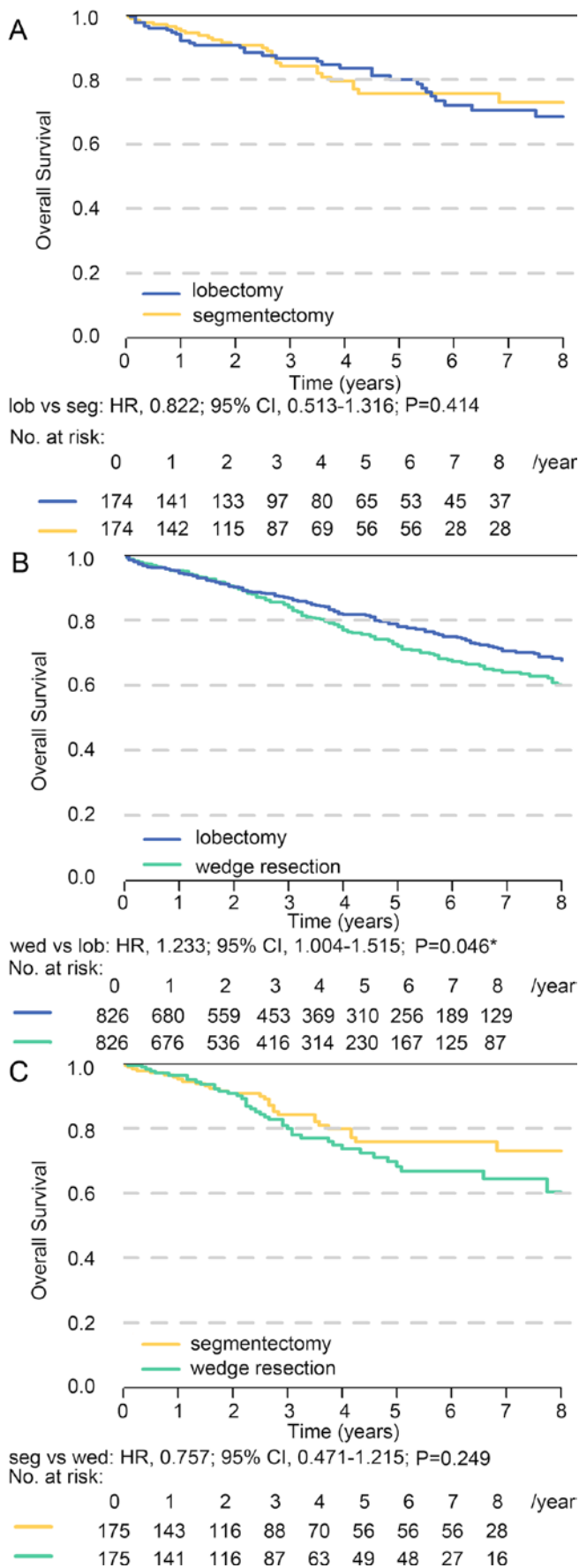
Figure 3. Comparison of overall survival between pairwise surgical procedures after PSM. Kaplan-Meier survival curve of overall survival of (A) lobectomy vs. segmentectomy, (B) wedge resection vs. lobectomy and (C) segmentectomy vs. wedge resection. PSM, propensity-score matching; HR, hazard ratio; CI, confidence interval.
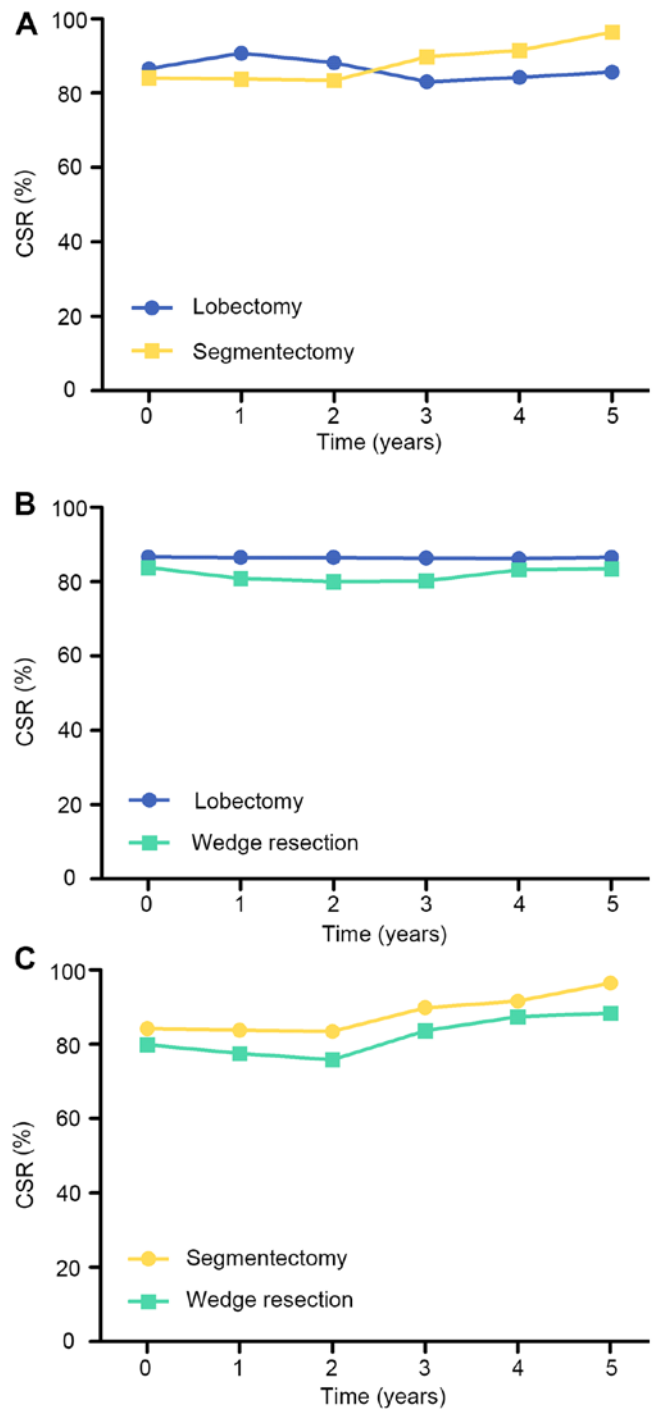

Figure 4. Comparison of CSR between pairwise surgical procedures. The changes in 3-year CSR of (A) lobectomy and segmentectomy, (B) lobectomy and wedge resection and (C) segmentectomy and wedge resection after PSM. CSR, conditional survival rate; PSM, propensity-score matching.

margins and nodes sampled during wedge resection. Notably, the CSR of segmentectomy was lower compared with that of lobectomy in the first two years but became higher after the 3rd year. This may be due to segmentectomy underestimating NSCLC stage due to deficient lymphadenectomy for hilar lymph nodes compared with lobectomy (29) and that a proportion of the patients were exposed to high risk of recurrence or metastasis and died in the first two years. The remaining patients have a better prognosis with retention of the pulmonary function (30). Altogether, segmentectomy may

Table VI. Balance between groups of patients undergoing segmentectomy and wedge resection for T1a before and after propensity score matching.

Variables	Full cohort			Matched cohort		
	Segmentectomy, n=175	Wedge resection, n=851	P-value	Segmentectomy, n=175	Wedge resection, n=175	P-value
Age, years, mean (± SD)	67.33 (9.85)	67.10 (9.99)	0.445	67.73 (9.85)	66.54 (9.29)	0.246
Sex, n (%)			0.137			0.516
Female	104 (59.43)	556 (65.33)		104 (59.43)	98 (56.00)	
Male	71 (40.57)	295 (34.67)		71 (40.57)	77 (44.00)	
Histology, n (%)			0.529			0.177
AD	129 (73.71)	597 (70.15)		129 (73.71)	123 (70.29)	
SC	25 (14.29)	151 (17.74)		25 (14.29)	37 (21.14)	
Other	21 (12.00)	103 (12.10)		21 (12.00)	15 (8.57)	
Grade, n (%)			0.041[a]			0.649
I	54 (30.86)	298 (35.02)		54 (30.86)	49 (28.00)	
II	71 (40.57)	252 (29.61)		71 (40.57)	65 (37.14)	
III-IV	26 (14.86)	159 (18.68)		26 (14.86)	33 (18.86)	
Undetermined	24 (13.71)	142 (16.69)		24 (13.71)	28 (16.00)	

[a]$P<0.05$. SD, standard deviation; AD, adenocarcinoma; SC, squamous cell carcinoma.

come at the price of insufficient lymphadenectomy but provide a compromise, for example greater conservation of the pulmonary function with promising long-term survival outcome.

The present study identified several factors, including age, sex, grade, histology and surgical procedures that were significantly associated with OS. This may partially explain heterogeneous survival of patients who undergo the same surgical procedure. To evaluate the effect of different operations on different factors, the CSR of the three surgical procedures was calculated based on stratification. In each subgroup analysis, the CSR of segmentectomy and lobectomy were higher compared with in wedge resection. Patients who initially had favorable clinicopathological characteristics, including ≤65 years-old or, grade I and who underwent segmentectomy, had CSR equivalent to that of the lobectomy group. However, patients with unfavorable conditions, such as advanced age displayed an expected trend, in that the segmentectomy CSR was lower compared with the lobectomy CSR in the early period but became higher in the later period. In patients with squamous cell carcinoma or other histological types, a similar trend was reported. In the adenocarcinoma group, the higher lobectomy CSR compared with that in the segmentectomy arm may be associated with that early metastasis in adenocarcinoma. Moreover, the insufficient lymph node dissection in sublobar resection does not favor prognosis (31). Further, in males, the segmentectomy CSR was equivalent to the lobectomy CSR overall. On the contrary, in females, the segmentectomy CSR was lower compared with lobectomy CSR in the early period but became higher in the later period. Similar results have been reported in lung cancer resection, however the cause of these differences remains unclear (32-34). Therefore, there is a need to conduct studies

on the response of different sexes to surgical procedures as well as tumor biology associated with physiological status in different sexes.

To the best of our knowledge, the present study is the first to assess CSR among patients with stage IA1 NSCLC using surgical procedures as a covariate. The CSR of surgical procedures based on the stratification of different prognostic factors was investigated. The aim of the present study was not to change the treatment paradigm, but to encourage wider application of CSR, that has not been studied before for patients with stage IA1 NSCLC, by comparing survival outcomes. The present results may contribute an additional insight to the prognosis of stage IA1 NSCLC, considering the dynamic survival probability.

There are limitations to the present study, inherent with using the SEER database. Firstly, the study had a retrospective design using SEER database, which presents with unavoidable selection bias. Although the apparent bias was compensated for using the Cox regression model and propensity-matched analysis, there still may have been some unknown latent biases, including preoperative physical condition, performance status and comorbidities among the treatment arms (35). Therefore, the impact of these covariates on the present findings could not be determined. Secondly, analysis was based on the postoperative pathological stage rather than the clinical stage. The clinical stage serves a more crucial role in decision making on the most appropriate surgical procedure to be administered to future patients. Thirdly, sublobar resection is more likely to apply to patients with poor physical status, for whom lobectomy is unsuitable (36). This may have caused some bias when comparing the prognosis of different surgical procedures. To minimize the impact of these aforementioned limitations, high-quality prospective studies need to be
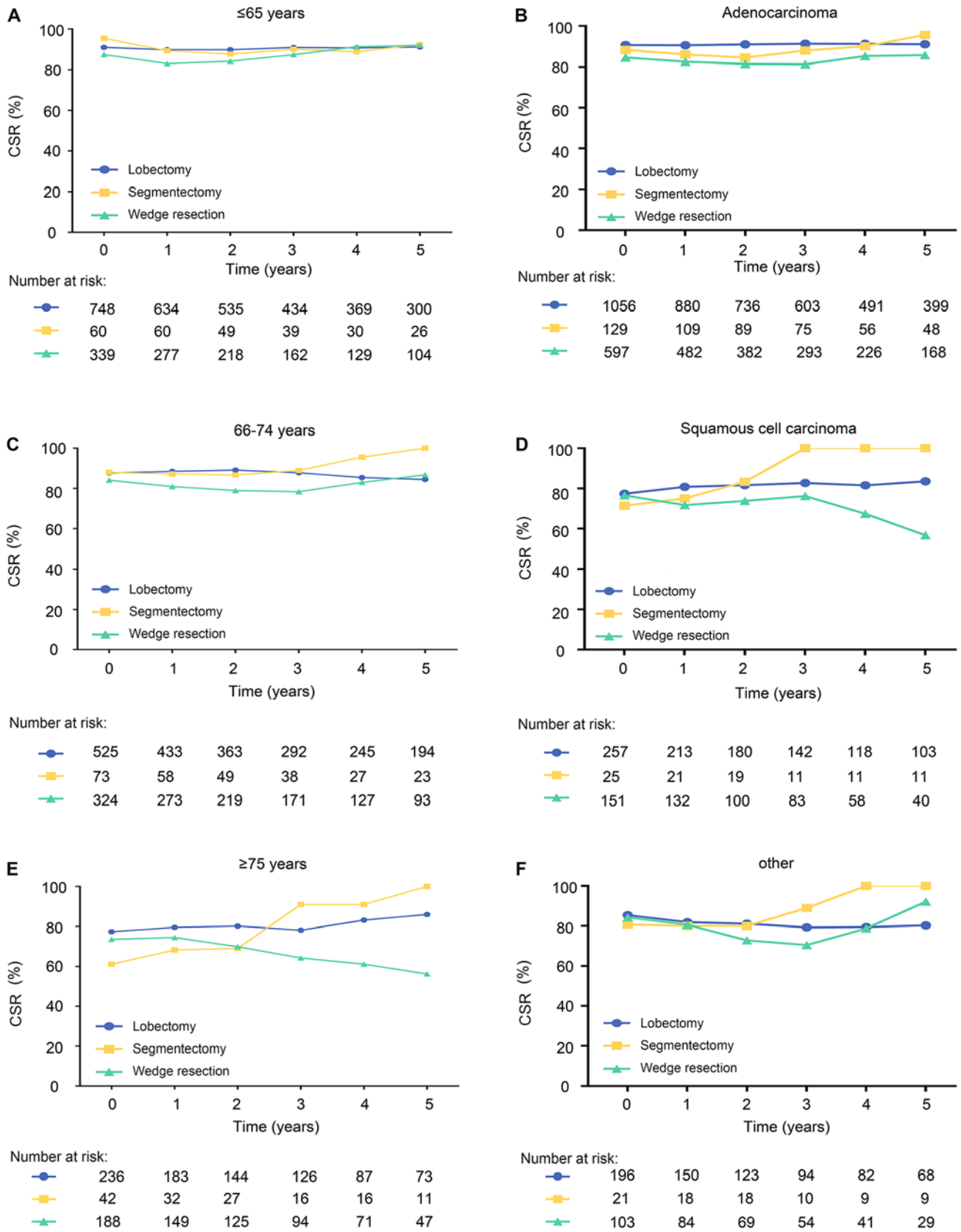
Figure 5. Comparison of CSR among three surgical procedures based on stratification according to age and histological type. The changes in 3-year CSR of (A) <65 year-old, (C) 66≤age≤74- and (E) >75 years old, (B) adenocarcinoma; (D) squamous cell carcinoma and (F) other histological types. CSR, conditional survival rate.

conducted to validate the present findings. Furthermore, the CSR is a semiquantitative concept, so it can only be compared

according to number, without indicating a statistically significant difference.
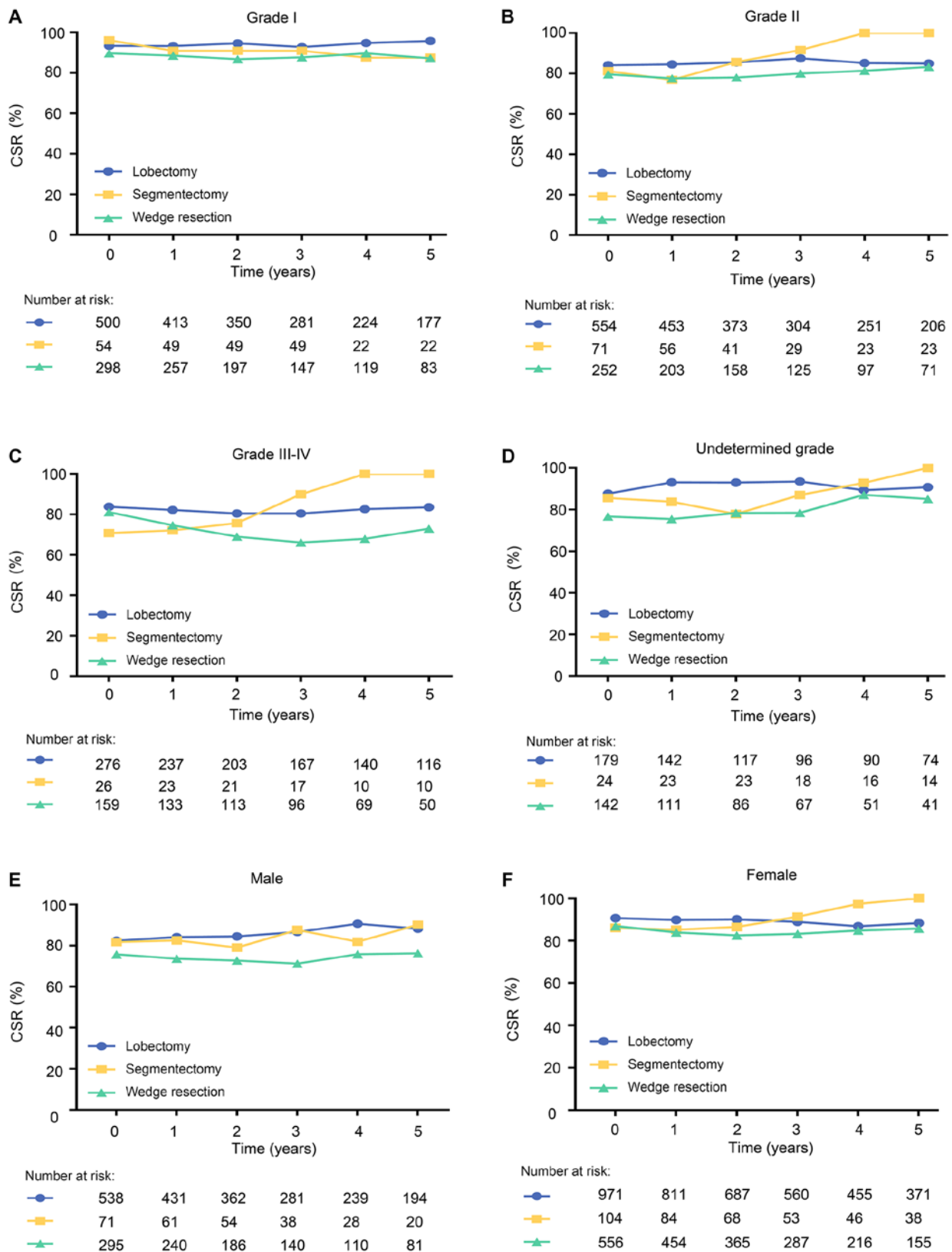
Figure 6. Comparison of CSR among three surgical procedures based on stratification according to grade and gentle. The changes in 3-year CSR of (A) Grade I, (B) II, (C) III-IV, (D) undetermined grade; (E) male; and (F) female. CSR, conditional survival rate.

In conclusion, to the best of our knowledge, the present study is the first to compare CSR concerning lobectomy, segmentectomy and wedge resection for patients with stage IA1 NSCLC. Consequently, these findings suggested that lobectomy is the most conservative surgical procedure for stage IA1 NSCLC. Additionally, the present findings pose interesting questions regarding the better long-term prognosis of segmentectomy in specific subsets of patients, such as females, patients ≥66 years

old, patients with squamous cell carcinoma or poor differentiation. Overall, the present study may contribute to improving treatment decision-making and update the prognosis of those patients with stage IA1 NSCLC.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available in the Surveillance Epidemiology and End Results repository (https://seer.cancer.gov).

Authors' contributions

SX, CY, XF, YB and YL conceived and designed the present study. SX, CY, XF and YB collected and assembled the data. All authors analyzed and interpreted the data, drafted and proofread the initial manuscript, and have read and approved the manuscript.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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