Predictors of Prognosis of Surgically Resected Brain Metastasis from Lung Cancer with a Focus on Brain Recurrence

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Abstract

Purpose: There are many considerations to decide surgical treatment in lung cancer-brain metastasis. Herein, we analyzed survival and predictors of brain recurrence after surgery for lung cancer-brain metastasis.

Methods: A total of 224 metastatic brain tumors from patients with lung cancer were analyzed.

Results: There were 138 (61.6%) male and 86 (38.4%) female patients; 197 patients with non-small cell lung cancer (NSCLC) and 27 with small cell lung cancer (SCLC). The rate of postoperative complications was 4.9%. The 1-year and 2-year overall survival (OS) was 57% and 43%, respectively. The 6-month and 1-year progression-free survival (PFS) of local recurrence was 42% and 20%, respectively. In NSCLC and SCLC groups, the difference of PFS of local recurrence according to adjuvant irradiation was not significant (1-year: 20% vs. 22%, $p=0.8$) and (1-year: 14% vs. 25%, $p=0.16$), respectively. Whole-brain irradiation did not show a significant difference of distant recurrence (6-month: 54% vs. 60%, $p=0.13$). In predictor analysis, female sex was a favorable prognostic factor for OS, while SCLC histology and postoperative neurological deficits were poor prognostic factors in univariate analysis.

Conclusions: SCLC histology and postoperative complications are negative predictors for OS. Adjuvant irradiation did not show effectiveness to reduce local and distant recurrence.

1. Introduction

Lung cancer is the most common cause of cancer-related death in South Korea¹. Brain metastasis is a major concern in the treatment of lung cancer. Sometimes, lung cancer is retrospectively diagnosed from brain metastatic mass. From the previous report, the incidence of brain metastasis in patients with primary lung cancer was 20%². Additionally, it has been reported that the incidence of lung cancer brain metastasis has been increasing in recent years, which places a great burden on public health services³. The treatment modalities of brain metastasis are surgery, conventional radiation therapy, systemic chemotherapy, and stereotactic radiosurgery (SRS). Recently, SRS including gamma-knife and cyber-knife radiosurgery has shown good results for local control for single and multiple brain metastasis; however, surgical resection still plays an important role. Surgery provides immediate relief of mass effect, obtaining tissue for histopathologic examination. In particular, surgical resection is the essential treatment in large metastasis. There are many considerations to decide surgical treatment in patients with lung cancer-brain metastasis, such as current disease state of lung cancer, performance status, tolerability for general anesthesia and craniotomy, expected survival after surgery, and postoperative neurological deficits. According to previously published studies, the median survival of lung cancer brain metastasis was reported at 3–12 months^{4–7}. Considering short survival and quality of life of patients with cancer, prediction of recurrence and survival is important during surgical decision-making. From a neurosurgeon's perspective, minimizing local and distant brain recurrence after surgery of metastatic tumor is the critical consideration and always have a question for adjuvant treatment after total resection of metastatic tumor. Herein, we investigated predictors of recurrence and survival of surgically treated brain metastasis from lung cancer.

2. Methods

2.1 Patient selection

This study was approved by the institutional review board of Asan Medical Center. Our institutional database was searched for metastatic brain tumors from lung cancer diagnoses between January 2010 and December 2020. Only newly diagnosed cases and patients who underwent microsurgery for lung cancer brain metastasis at our institute were enrolled in the current study; recurrent tumors with no available information, brain metastasis from other primary tumors were excluded. A total of 224 patients with metastatic brain tumors from lung cancer treated by surgical resection and confirmed on histopathological examination were initially included in the study population. The tumor size was defined by its maximal diameter in two dimensions.

2.2 Treatment and follow-up

Treatment decision of lung cancer brain metastasis has been established in "Integrated lung cancer treatment team," comprising oncologists, radiation-oncologists, and neurosurgeons. The extent of resection in our study was re-defined as follows: gross total resection, complete removal of the tumor as indicated on postoperative magnetic resonance imaging (MRI); subtotal resection, any incomplete resection of the tumor with less than 10% of the tumor visible as a remnant on postoperative MRI. SRS including gamma-knife (GK) radiosurgery (RS) and cyber-knife (CK) RS were additionally performed for residual tumors. GKRS was performed using a

Leksell GK perfexion (December 2011 until the present). Dose planning for the GKRS treatments used MRI analysis in the Leksell gamma plan. The Elekta and marginal prescription doses were from 20 to 24 Gy. The Robotic Radiosurgery System Version 9.0 was used for CK treatments. For CK planning, computed tomography images of a very thin slice (0.625 mm thickness with no slice gap) were obtained and fused with gadolinium-enhanced axial and coronal three-dimensional T1-magnetization-prepared rapid acquisition gradient-echo MR images (1.0 mm slice) in the Accuray MultiPlan system (version 4.5). The median prescription dose was 35 Gy (range: 25–41 Gy), the dose was administered in three or five daily fractions. Conventional radiation therapy was administered for the surgical cavity or whole brain, the prescription dose was 30 Gy and was fractionated by 2 or 3 Gy.

Initial follow-ups involved clinical evaluations and an MRI in the immediate postoperative period (within 48 h), and at 1 and 3 months, and then checked every 3 months.

2.3 Statistical analysis

Subgroup comparisons were performed using a Student's *t*-test, Chi-square test, or Fisher's exact tests. Overall survival (OS) and progression-free survival (PFS) were evaluated in addition to prognostic factors. The OS and PFS outcomes were analyzed using Kaplan-Meier survival analysis, and subgroup comparisons were performed using log-rank tests. Potential prognostic factors for PFS, including age, sex, multiple metastases, adjuvant resection bed irradiation, adjuvant whole-brain radiation therapy (WBRT), the period from lung cancer diagnosis to brain metastasis, postoperative neurological sequelae, immunohistochemical findings in NSCLC were analyzed using a Cox-proportional hazards model. The proportional hazards assumption was confirmed by the testing of Schoenfeld residuals, and no relevant violations were found. All statistical analyses were conducted using SPSS ver. 21.0 (IBM Corp., Armonk, NY). A *p*-value < 0.05 was considered statistically significant.

3. Results

3.1 Study patient characteristics and treatment outcomes

There were 138 (61.6%) male and 86 (38.4%) female patients with a median age of 60 years. There were 197 patients with non-small cell lung cancer (NSCLC) and 27 with small cell lung cancer (SCLC). Among patients with NSCLC, 52.3% patients were epidermal-growth factor receptor (EGFR)-mutant, and 47.7% were EGFR non-mutant. Among patients with NSCLC, the initial stage was stage 4 in 54.6% and extended disease among 88.8% of SCLC patients. The most common location was the frontal lobe (32.6%) following the cerebellum (17.9%) and temporal lobe (14.3%). The representative image findings were presented in Figure 1. One hundred five (73.7%) patients had single brain metastasis and 59 (26.3%) had multiple brain metastasis. The maximal diameter was 42 mm. The median period from lung cancer diagnosis to brain metastasis was 8 months; however, one patient showed 226 months recurrence in the brain from complete remission of lung cancer. The rate of postoperative complications was 4.9%. Twenty-eight patients (12.5%) received conventional radiation therapy and 49 (21.8%) patients received SRS. The median follow-up period was 12 months. The detailed characteristics were presented in Table 1.

3.2 Progression-free and overall survival between groups

The 1-year and 2-year OS rates of patients with lung cancer brain metastasis were 57% and 43%, respectively. The 6-month and 1-year PFS of local recurrence was 42% and 20%, respectively and distant recurrence was 54% and 24%, respectively. (Figure 2). In terms of Recursive Partitioning Analysis (RPA) classification, RPA class 1 group showed longer survival compared to class 2 and 3 groups (*p*=0.04).

NSCLC vs. SCLC: The 1-year and 2-year OS of NSCLC was 58% and 42%, respectively, and the 1-year and 2-year OS of SCLC was 44% and 10%, respectively. The difference of OS between NSCLC and SCLC was statistically significant (*p*=0.01). The 6-month and 1-year PFS of local recurrence of NSCLC was 51% and 20%, respectively and SCLC was 36% and 18% months, respectively (*p*=0.35). The 6-month and 1-year PFS of distant recurrence of NSCLC were 56% and 19%, and SCLC was 56% and 18%, respectively. (Figure 2)

Adjuvant resection bed irradiation and WBRT: In the NSCLC group, the difference of PFS of local recurrence according to adjuvant resection bed irradiation was not significant (6-month: 38% vs. 66%, 1-year: 20% vs. 22%, *p*=0.8). In the SCLC group, the difference of PFS of local recurrence according to adjuvant resection bed irradiation was also not significant (6-month: 14% vs. 75%, 1-year: 14% vs. 25%, *p*=0.16). Whole-brain irradiation did not show a significant difference in PFS of distant recurrence (6-month: 54% vs. 60%, *p*=0.13). Leptomeningeal seeding occurred in 38 (17%) patients during treatment, WBRT group did not show superiority for leptomeningeal seeding (1-year PFS rate: non-WBRT group= 85.9%, WBRT group=81.8%, *p*=0.87). (Figure 3)

Postoperative complications: The postoperative complications occurred in 11 patients. Patients who experienced postoperative complications showed statistically significant shorter OS than those who did not experience postoperative complications (1 year: 59% vs. 27%, $p=0.03$). (Figure 3-[D])

Immunohistochemical findings: EGFR, anaplastic lymphoma kinase-1 (ALK-1), programmed death ligand-1 (PD-L1) are known as the therapeutic target of NSCLC. In terms of EGFR, EGFR mutation did not show significant difference of PFS for local recurrence (6-month: 29% vs. 54%, 1-year: 11% vs. 25%, $p=0.16$) and distant recurrence (6-month: 56% vs. 56%, 1-year: 25% vs. 18%, $p=0.22$). However, the EGFR mutant group showed statistically significant longer OS than EGFR non-mutant group (2-year: 38% vs. 53%, $p=0.04$) (Figure 3). ALK mutation and PD L1 mutation did not show significant differences in PFS (local recurrence and distant recurrence) and OS. (Figure 4)

3.3 Prognostic indicators of progression-free survival and overall survival

We analyzed predictors of local, distant recurrence and OS including age, sex, multiple metastases, SCLC histology, resection bed irradiation, WBRT, the period from lung cancer diagnosis to brain metastasis shorter than 12 months, postoperative neurological deficits, and immunohistochemical findings (EGFR mutation, ALK-1 mutation, and PD-L1 mutation). In univariate analysis, female sex was a favorable prognostic factor for PFS for distant recurrence, as well as for OS; however, SCLC histology and postoperative neurological deficits were negative predictors for OS. In multivariate analysis, ALK-1 mutation showed intermediate significance for local recurrence. There was no significant predictor for distant recurrence. Female patient and postoperative neurological deficits were statistically significant predictors for OS (HR=0.5 [95% CI: 0.3–0.7, $p=0.01$] and HR=2.46 [95% CI=1.28–7.72, $p=0.01$]). Detailed analysis was presented in Table 2.

4. Discussion

Lung cancer is the most frequent source of metastatic brain tumors. It occurs in 17–65% of patients with primary lung cancer^{3,8}. The rate of lung cancer brain metastasis has been increasing in recent years³. According to previously published studies, the prognosis for patients with lung cancer brain metastasis is poor, median OS of lung cancer brain metastasis was reported from 1 to 12 months despite treatment^{4–6}. However, there are significant advances in the management of lung cancer, to our study, the median OS was over 12 months.

To prolong the survival and improve the quality of life of lung cancer brain metastasis, neurological symptom and relief intracranial hypertension, the treatment of brain metastasis is critical in patients with lung cancer. Thus, the role of a neurosurgeon is considerably important in the treatment of lung cancer brain metastasis. From the perspective of a neurosurgeon in brain metastasis treatment, decreasing local and distant recurrence with maintaining or improving the life of quality are the most important considerations. Surgery, stereotactic radiosurgery, conventional radiation therapy, and systemic chemotherapy are the possible treatment strategies in brain metastasis. The efficacy of radiosurgery for small-sized oligometastasis has been proved⁷. Moreover, Chon et al. reported the feasibility of fractionated radiosurgery for medium-sized brain metastasis⁹. However, for medium to large tumors, surgical resection is still an essential tool. Moreover, surgery is the only option for large tumors with mass effect, establishing pathological confirmation, progression after radiosurgery, or radiotherapy. Recently, we have performed surgical resection at our institute of not only single metastasis or oligo-metastasis but also multiple metastases. Surgery with adjunctive radiosurgery or radiotherapy were performed to prolong survival or relieving symptoms related to brain metastasis.

In this study, we focused on analyzing predictors for local and distant recurrence of the brain from a neurosurgeon's perspective. Total resection of metastatic brain tumor was performed for 97% of patients. To reduce local recurrence, "en-bloc"-resection showed a better outcome than "piecemeal resection"¹⁰. Furthermore, Yoo et al. reported plus 5 mm adjacent white matter resection reduced local recurrence¹¹. In our series, we did gross total resection without plus normal tissue resection. Although, all tumors could not be feasible, to reduce local recurrence rate, "en-bloc"-fashion resection plus white matter is pursued for non-eloquent area tumors.

Postoperative radiotherapy and SRS for reducing local recurrence could be applied in the resection cavity. SRS and WBRT showed comparable results for local recurrence in brain metastasis^{6,12}. In the previous report, the efficacy of SRS and WBRT are comparable^{6,12,13}. WBRT has been needed for disseminated metastasis and it harbored a unique role, however, considering the neuro-cognitive complications including learning and memory dysfunction, SRS may be a more suitable tool for resection bed irradiation¹⁴.

Theoretically, resection bed irradiation may provide good local control, but poor distant recurrence control. However, in our series, resection bed radiotherapy and radiosurgery did not affect the local recurrence of both NSCLC and SCLC brain metastasis. Additionally, postoperative WBRT failed to affect the distant recurrence. It implicated adjuvant radiotherapy and radiosurgery may not be mandatory after surgical resection for lung cancer brain metastasis. In the previous studies, only WBRT for brain metastasis impact survival from 1 to 3 months^{15,16}. Applying WBRT for reducing distant recurrence in lung cancer brain metastasis considering its survival benefit and neurocognitive impairment is still debatable. According to our result, WBRT did not improve the PFS for distant recurrence.

At our institute, there was no consensus for applying adjuvant radiotherapy or SRS, it depends on the opinion of individual oncologists. Standard cytotoxic chemotherapy used in lung cancer, mainly platinum agents is not effective for lung cancer brain metastasis owing to poor penetration of the blood-brain barrier⁴. Molecular targeted therapy showed the promising effect of lung cancer-NSCLC brain metastasis^{4,17}. EGFR mutation, ALK rearrangement, and PD-L1 are targetable mutations. They have shown effectiveness in intracranial disease control; moreover, a recent clinical trial reported the promising result of EGFR-targeted therapy for the leptomeningeal disease¹⁸. However, still, they are not suitable for symptomatic and immediate life-threatening brain metastasis, it could be applied for small metastasis and disseminated disease. At our institute, we have used a molecular targeted agent after surgical resection of metastatic brain tumor according to the status of targetable gene mutation. We evaluated the difference of local recurrence and distant recurrence concerning EGFR, ALK-1, and PD-L1 in the NSCLC group. There was no statistically significant difference in local and distant recurrence. EGFR mutant NSCLC brain metastasis group showed superior OS rate, which may be attributed to extracranial disease control by EGFR-target agent. The efficacy of molecular target agent after brain metastatic tumor resection should be evaluated at the future study.

The maintenance of the quality of life of patients with cancer is an important consideration. Considering the lower chance of cure of disease in patients with lung cancer brain metastasis, the postoperative complication significantly impacting the performance status of patients should be minimized. In recent studies, the eloquent location of metastatic brain tumors could be managed using radiosurgery^{7,9}. Declining of performance status due to postoperative neurological deficits not only restrict further chemotherapy or radiation therapy but also leads to other medical complications, which jeopardize the survival of patients with lung cancer. In our study, the postoperative complication group showed a significantly lower OS rate. We should minimize the postoperative complication in lung cancer brain metastasis surgery, and consider that the complication critically influences survival.

Study limitations and strengths

Our current study had some limitations. In the first instance, it was a retrospective investigation that included 224 patients with lung cancer brain metastasis. Along with the limitations inherent to any retrospective design, this precluded less meaningful multivariate analysis of survival outcomes or predictors of local and distant recurrence. This study series spanned around 10 years; therefore, the treatment methods varied. Additionally, the management strategy of lung cancer brain metastasis was varied according to individual neurosurgeons, which made it challenging to conclude on the optimal intervention strategies and outcomes in these cases.

Our study also had some notable strengths. However, including our finding that the SCLC and postoperative complication groups have a significantly shorter OS than the adjuvant resection bed RT and SRS, usage of targeted therapy after resection may not be a predictive factor for local and distant recurrence in lung cancer brain metastasis. Although we could not draw any meaningful conclusions to assist with future treatment guidelines, our analysis indicates that female sex, SCLC histology, and postoperative complications are prognostic indicators in terms of survival, and require careful consideration to improve survival and maintain the quality of life in metastasis. Therefore, we believe that the data from our current single-center series make a valuable contribution to the available literature on these extremely rare tumors and to a future meta-analysis of this disease.

5. Conclusion

Surgery of lung cancer brain metastasis is an essential treatment tool to improve survival and defer life-threatening events during lung cancer treatment. SCLC histology and postoperative complication are negative predictors for OS. Adjuvant SRS, RT, and targeted chemotherapy do not show effectiveness to reduce local and distant recurrence. However, a future large-sized study should be conducted.

Declarations

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Authors' contributions

Author contributions JB and YHK conceived and designed the study. MK and SL conducted the literature search. JB, MK, YHK, SWS and CKH were involved in the analysis and interpretation of data. JB drafted the manuscript. The study was supervised by CKH and JHK. All authors read and approved the final manuscript.

The authors declare no competing interests regarding this study.

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Ethics approval

This retrospective study has been approved by the appropriate ethics committee and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. (Approval by IRB of Asan Medical Center, No. 2021-1137). For this type of study, formal patient consent is not required. The IRB of Asan Medical Center gave the right of exemption of 'informed consent' for this study. The reason described below.

The risk expected from this 'retrospective observational study' is not greater than the Level I risk. In addition, all of included patients' dataset were anonymized. There is no reason to presume the refusal of the research subject's consent, and the risk to the enrolled patients is extremely low even if consent is waived. Consent exemption does not infringe on the rights or welfare of the subject. It is not the research for drug/medical device approval, and it is not a research regulated by a foreign regulatory agency.

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Tables

Table 1. Basal characteristics of enrolled patients

	Total N=224
Age	Median 60 (27–79)
Sex	
Male	138 (61.6%)
Female	86 (38.4%)
Histology	
NSCLC	197 (87.9%)
Squamous	37
Adenocarcinoma	145
Others	15
NSCLC-EGFR mutant	52.3%
NSCLC-EGFR non mutant	47.7%
Small cell carcinoma	27 (12.1%)
Initial lung cancer stage	
NSCLC	
I	33
II	15
III	41
IV	107
SCLC	Total=27
Limited	3
Extended	24
Location of tumor	
Frontal	73 (32.6%)
Parietal	56 (25%)
Temporal	32 (14.3%)
Occipital	22 (9.8%)
Cerebellum	40 (17.9%)
Others	1 (0.4%)
Single brain metastasis	165 (73.7%)
Multiple brain metastasis	59 (26.3%)
Period from lung cancer diagnosis to brain metastasis (months, median)	8 (0–226)
Extracranial metastasis	
Absence	159 (71%)
Presence	65 (29%)
RPA class	
Class 1	28 (12.5%)
Class 2	108(48.2%)

Class 3	88 (39.3%)
Maximal diameter of tumor (mm, median)	42 (10–80)
Extent of resection	
Total resection	218 (97.3%)
Subtotal resection	6 (2.7%)
Postoperative complication	11 (4.9%)
ICH	6
EDH	2
Infarction	3
Adjuvant radiotherapy	28 (12.5%)
Conventional RT	
- Resection bed	11
- Whole brain	17
Stereotactic radiosurgery	
- Resection bed	19
- Another metastatic lesion	30
Adjuvant CTX	
Non-target agents	101 (45.3%)
Target agents	71 (31.7%)
Follow-up period (median, month)	12 (0–119)

NSCLC: non-small cell lung cancer, SCLC: small cell lung cancer, EGFR: epidermal growth factor receptor, EDH: epidural hemorrhage, ICH: intracerebral hemorrhage, RT: radiation therapy, CTX: chemotherapy, KPS: Karnofsky Performance Scale, RPA: recursive partitioning analysis

Table 2. Predictors of prognosis of surgically resected lung cancer brain metastasis (Cox-proportional hazard analysis)

Univariate analysis							Multivariate analysis						
	PFS (Local recur)		PFS (Distant recur)		Overall survival		PFS (local recur)		PFS (distant recur)		Overall survival		
	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	
Age													
>60 years	1.13 (0.67–1.89)	0.63	1.15 (0.73–1.81)	0.52	1.22 (0.88–1.69)	0.22	NA						
Sex													
Female	0.68 (0.40–1.16)	0.16	0.63 (0.40–1.00)	0.05	0.47 (0.33–0.67)	0.01	0.66 (0.38–1.12)	0.13	0.69 (0.42–1.13)	0.15	0.50 (0.35–0.72)	0.01	
Multiple metastasis	0.89 (0.51–1.54)	0.68	0.49 (0.94–2.36)	0.08	1.31 (0.91–1.87)	0.13	NA		1.39 (0.87–2.22)	0.16	1.31 (0.91–1.89)	0.13	
NSCLC							NA						
SCLC	1.27 (0.63–2.53)	0.49	1.38 (0.79–2.42)	0.24	1.83 (1.15–2.91)	0.01			1.15 (0.63–2.12)	0.63	1.51 (0.94–2.43)	0.08	
Adjuvant resection bed irradiation	0.82 (0.44–1.53)	0.54	NA		0.96 (0.64–1.45)	0.86	NA		NA		NA		
Adjuvant WBRT	NA		0.93 (0.76–4.88)	0.16	0.71 (0.37–1.36)	0.31	NA		1.96 (0.76–5.02)	0.16	NA		
Period from lung cancer diagnosis to brain meta	0.82 (0.48–1.38)	0.46	1.17 (0.74–1.84)	0.49	0.82 (0.59–1.15)	0.25	NA		NA		NA		
< 12 months													
Over 12 months													
Postoperative neurological deficits	3.8 (0.50–28.92)	0.19	1.79 (0.43–7.37)	0.41	2.52 (1.32–4.8)	0.01	4.89 (0.62–38.18)	0.13	NA		2.46 (1.28-7.72)	0.01	
NSCLC													
EGFR mutant	0.63 (0.34–1.15)	0.13	0.81 (0.47–1.37)	0.43	0.52 (0.07–3.76)	0.51	0.54 (0.12–2.44)	0.42	1.67 (0.53–5.18)	0.37	0.73 (0.30–1.77)	0.49	
ALK mutant		0.95		0.88		0.96				0.98		0.70	
PD-L1 positive	0.95 (0.32–2.79)	0.7	1.06 (0.47–2.37)	0.94	0.98 (0.52–1.86)	0.08	7.2 (0.99–52.75)	0.49	1.01 (0.22–4.57)	0.94	0.80 (0.25–2.52)	0.08	
	0.80 (0.26–2.4)		1.03 (0.39–2.71)		2.1 (0.9–4.89)		0.6 (0.15–2.51)		1.03 (0.94–1.03)		2.26 (0.9–5.62)		

NSCLC: non-small cell lung cancer; SCLC: small cell lung cancer; PFS, progression-free survival; HR: hazard ratio; CI: confidence interval; WBRT: whole brain radiation therapy; EGFR: epidermal growth factor receptor; ALK: anaplastic lymphoma kinase; PD-L1: programmed death ligand-1

Figures

Figure 1

Representative radiological findings for brain metastasis from lung cancer (A-1,2) A 52-year-old male patient with non-small cell lung cancer (NSCLC)-squamous cell carcinoma. A large right frontal lobe tumor is resected to relieve intracranial hypertension. Other lesions were treated by gamma knife radiosurgery. (B-1,2) A 65-year-old male patient with NSCLC-adenocarcinoma. Left temporal lobe large cystic tumor is resected totally. Another small right parietal tumor is treated by gamma knife radiosurgery. (C-1,2) A 70-year-old male patient with NSCLC adenocarcinoma. Single left occipital solid and the cystic tumor is resected. Postoperative homonymous hemianopsia is developed. The patient has not received adjuvant therapy. (D-1,2) A 79-year-old male patient with NSCLC squamous cell carcinoma. A large cystic cerebellar tumor is resected to relieve obstructive hydrocephalus. Postoperatively, the fourth ventricle is decompressed and hydrocephalus is relieved.

Figure 2

Kaplan-Meier survival analysis of the enrolled patients (A) Overall survival (OS) of all surgically treated patients with lung cancer brain metastasis. (B) Progression-free survival (PFS) of local recurrence of all surgically treated patients with lung cancer brain metastasis. (C) PFS of distant recurrence of all of the surgically treated patients with lung cancer brain metastasis. (D) The difference of OS between non-small cell lung cancer (NSCLC) and small cell lung cancer (SCLC) groups. NSCLC group shows better overall survival after surgical resection of brain metastasis. (E) The difference of PFS for local recurrence between NSCLC and SCLC group. There is no significant PFS difference. (F) The difference of PFS for distant recurrence between NSCLC and SCLC group. There is no significant PFS difference.

Figure 3

Kaplan-Meier survival analysis of the enrolled patients (A) The difference of progression-free survival (PFS) for local recurrence for resection bed adjuvant radiotherapy in the NSCLC group. There is no statistically significant PFS difference. (B) The difference of PFS for local recurrence for resection bed adjuvant radiotherapy in SCLC group. The adjuvant radiotherapy group shows better PFS for local recurrence than no adjuvant radiotherapy group. However, this result was statistically insignificant. (C) The difference of PFS for distant recurrence regarding adjuvant whole-brain irradiation (WBRT). There is no statistically significant difference in PFS for distant recurrence. (D) The development of postoperative complications affects the overall survival of lung cancer brain metastasis.

Figure 4

Kaplan-Meier survival analysis of the enrolled patients Overall survival (OS), progression-free survival (PFS) for local and distant recurrence according to immunohistochemical findings of non-small cell lung carcinoma (NSCLC). (A-1,2,3) The OS and PFS difference according to epidermal growth factor receptor (EGFR) mutation in the NSCLC group. There was no significant difference in PFS for local and distant recurrence. However, the EGFR mutant group showed better OS than EGFR non-mutant group. (B-1,2,3) The OS and PFS difference according to anaplastic lymphoma kinase-1 (ALK-1) mutation in the NSCLC group. There was no significant difference in OS, PFS for local and distant recurrence according to ALK-1 mutation. (C-1,2,3) The OS and PFS difference according to programmed death-ligand 1 (PD-L1) mutation in the NSCLC group. There is no significant difference in OS, PFS for local and distant recurrence according to ALK-1 mutation. (PD-L1 expression rate above 20%).