Medicine®

Comparison of survival outcomes after CyberKnife® radiotherapy in Taiwan using preapproved insurance-based reimbursement versus out-of-pocket expenditure

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Abstract

Background: With technological advances, radiotherapy has progressed from simple irradiation to robotic arm-based stereotactic radiosurgery systems (SRS, in this case, CyberKnife®). This equipment is high-priced and might be cost-effective or not. The National Health Insurance (NHI) in Taiwan has a premedical claims review process for approving CyberKnife® treatment; however, patients might have to pay for the procedure themselves if the NHI rejects the practice. Under the high treatment cost and such an insurance system, a sketch of patients treated by these high-cost machines and whether the prereview of insurance for reimbursement is reasonable without hindering the patient's right to undergo treatment should be investigated. In this study, the patients of CyberKnife® radiotherapy in our institute were investigated as an example for this purpose.

Methods: Patients who underwent CyberKnife® radiotherapy in our department were investigated retrospectively. Their demographic characteristics, disease patterns, and treatment sites were analyzed. Survivals were compared according to clinical features, and treatment expenses were reimbursed after prereview or out-of-pocket.

Results: From October 19, 2014, to January 30, 2018, there were 331 patients included in this study, 205 (55.3%) of whom underwent CyberKnife® radiotherapy at their own expense, while 166 (44.7%) had their expenses approved for reimbursement after prereview by NHI. Most patients were treated for metastatic tumors (37.5%), and the brain was the most frequent treatment site (46.1%). The 1-year overall survival was 67.1%, and the 2-year overall survival was 56.3% after CyberKinfe® radiotherapy. The best survival rate (96.8% at 1 year) was for patients with brain tumors. In patient's characteristics, A better Eastern Cooperative Oncology Group (ECOG) performance status, treatment for primary tumors, and outpatient treatment were independent factors for superior survival after CyberKnife® radiotherapy. The survivals for patients whose treatment expenses were approved for reimbursement after prereview by NHI were also better than out-of-pocket.

Conclusions: Besides the patients' characteristics, the treatment expense could be approved or rejected for reimbursement by the NHI prereview was an independent factor for survival in CyberKnife® radiotherapy. Prereview to reimburse expensive treatment is not an unreasonable requirement.

Abbreviations: ECOG = Eastern Cooperative Oncology Group, KPS = Karnofsky performance status, NHI = National health insurance, PS = performance status, SBRT = stereotactic body radiation therapy SBRT, SR = survival rate, SRS = Stereotactic radiosurgery, WHO = World Health Organization

Keywords: CyberKnife, high-cost, National Health Insurance, prereview, radiotherapy, reimbursement, survival

1. Introduction

X-rays were discovered by Wilhelm Conrad Roentgen in 1895 and have been applied to disease treatment for more than 100 years. Advances in radiation therapy equipment and technologies are rapid. Treatment technologies have evolved from 2-dimensional radiation therapy, 3-dimensional conformal radiation therapy, and intensity modulation radiation therapy to the most accurate stereotactic radiosurgery (SRS). A sophisticated treatment requires integrating different systems on machines and staffing with different expertise. CyberKnife® (Accuray Inc., Sunnyvale, CA, USA) is equipment like this in radiotherapy. The system has a linear accelerator mounted on a robotic arm. Using computer-based stereo positioning guidance and a real-time

image guidance detector according to the patient's movements to ensure that the radiation rays are delivered accurately to the treatment target makes SRS execution more accessible and precise.[1] Furthermore, the robotic arm-based system can treat intracranial lesions and the body called stereotactic body radiation therapy (SBRT).[2,3] Such a machine looks ideal for clinical use in radiation therapy, but the cost is very high, and the treatment is also costly.

From the perspective of hospital operation and management, investing in high-priced equipment may not be able to balance the profits and losses. From the patient's point of view, the cost of treatment may be too high to afford. The health insurance system may play a vital role in the dilemma of high-cost medical equipment treatment. Fortunately, Taiwan's people have a national healthcare system, known as National Health Insurance (NHI), a single-payer compulsory social insurance plan that centralizes the disbursement of healthcare funds. The system promises equal access to healthcare for all citizens, and the population coverage had reached 99% by the end of 2004.[4] Mutual assistance is the central concept of NHI. People can choose to visit any hospital and doctor if they need medical care. Therefore, the accessibility to the healthcare system is excellent, and the patients don't have to worry about medical bills. However, there is still premedical claims review according to the benefits package for high-cost treatment, CyberKnife® radiotherapy as well. Therefore, not all patient's high-cost therapies suggested by the clinician can be approved by prereview for reimbursement. If the prereview rejects the treatment, patients can still pay by themselves for the treatment they decide.

Under the high treatment cost of such an insurance system, a sketch of patients treated by these high-cost machines be disclosed. Whether the prereview of insurance for reimbursement is reasonable without hindering the patient's right to undergo treatment should also be investigated. These results should be significant for hospitals in the decision, management, and operation. In this retrospective study, we reviewed the patients who underwent radiotherapy by CyberKnife® in our institute to analyze their characteristics, disease patterns, treatment sites, and possible factors for survival as a reference for improving the benefits of the high-cost treatment.

2. Methods

2.1. Participants

The patients who underwent CyberKnife® radiotherapy in our department from October 19, 2014, to January 30, 2018, were reviewed. The patients were transferred or registered by themselves to our department. Patients who were verified as having indicated diseases, benign tumors, malignant tumors, local reoccurrence, metastatic cancer through diagnostic imaging, and those diagnosed as having primary malignant tumors through pathology proof; were evaluated as suitable for CyberKnife® treatment by physicians.

2.2. Data collection

Patients' demographic data were documented, including age, sex, educational attainment, marital status, place of residence, history of chronic diseases (e.g., diabetes, heart disease, hypertension, stroke, renal diseases, etc.), performance status (PS) determined by the Eastern Cooperative Oncology Group (ECOG) scale, disease type, disease status, location of treatment, treatment dose, frequency, whether patients were hospitalized during treatment, whether patients took oral steroids during their treatment, whether patients had been prescribed other medication after treatment and treatment costs could be reimbursed by prereview process or not.

After the clinician's assessment, if the patient was indicated for CyberKnife® treatment, the benefits must be reviewed and approved for reimbursement before treatment according to the NHI payment standard. Once the benefits are rejected, the patient could pay by himself for treatment or consider conventional radiation therapy, which NHI covered without necessary prereview. The patient could also pay by himself for CyberKnife® radiotherapy due to non-compliance with health insurance benefits or not being willing to wait for review. The indicated criteria for reimbursement of CyberKnife® radiotherapy by NHI are described in Supplementary Digital Content 1, http://links.lww.com/MD/G982.

2.3. Statistical analyses

The patients were followed until April 2, 2018. The patients who did not visit our hospital after treatment were contacted by phone calls. For data analysis, the statistical software package SPSS 23 (IBM SPSS®) was adopted. For univariate analysis, the Kaplan–Meier estimator was adopted to calculate the survival, and the log-rank test was used to analyze the differences between the relevant factors of CyberKnife® radiotherapy. For multivariate analysis, Cox regression was adopted to analyze independent factors. The threshold of statistically significant was taken as $P < .05$.

2.4. Ethical consideration

This study was subjected to a previous review and authorized by the Chang Gung Medical Foundation Institutional Review Board No.201900567B0.

3. Results

From October 2014 to January 2018, 371 patients underwent CyberKnife® radiotherapy in our department, 205 of whom (55.3%) underwent CyberKnife® radiotherapy at their own expense, whereas 166 (44.7%) had their reimbursement approved by the NHI after prereview. The demographic characteristics of patients in this study are listed in Table 1. More male patients (n=232, 62.5%) than female patients (n=139, 37.5%) were treated and males (n=150, 73.2%) accounted for a larger proportion of out-out-pocket patients for CyberKnife® radiotherapy. Their ages ranged from 9 to 91 years, and the mean age was 58.6. Most patients were married (n = 285, 73.8%), with 81.0% (166/205) of the patients who paid out-of-pocket being married. In terms of educational level, 56.2% (n = 195) had a high school education, with 55.1% (n = 113) of the out-of-pocket patients having at least a high school education. The patients mostly resided in Kaohsiung City (n = 255, 68.7%), where our hospital is located, followed by neighboring Pingtung County (n = 78, 21.0%). In total, 189 patients (49.6%) had no other chronic diseases or comorbidities. The most common comorbid chronic disease was hypertension (n = 94, 25.3%), followed by diabetes (n = 28, 7.5%). Sixty patients (16.2%) had 2 or more chronic diseases.

Regarding primary tumor site, the most common was lung cancer (n = 114, 30.7%), followed by brain lesions (n = 69, 18.6%). Among the out-of-pocket patients, only 2 patients (1.0%) were primary brain tumors. Table 2 shows the patients' PS, with most patients (n = 357, 96.2%) scoring no worse than an ECOG 2. Table 3 presents the treatment targets at the time of the CyberKnife® radiotherapy. Most patients were treated for metastatic tumors (n = 139, 37.5%). Table 4 presents the treatment sites, with most patients being treated in the brain (n = 171, 46.1%), following by the head and neck (n = 75, 20.2%) and lungs (n = 52, 14.0%). Most patients underwent treatment in the outpatient clinic (n = 255, 68.7%), while 166 patients (n = 116, 31.3%) were treated in the hospital. In terms of treatment

Table 1

Patient characteristics between the treatment expanse reimbursed after NHI prereview and out-of-pocket.

Characteristic	Treatment expanse reimbursed after NHI prereview (n=166)	Out-of-pocket (n=205)
Gender		
Male	82(49.4%)	150(73.2%)
Female	84(50.6%)	55(26.8%)
Ages, mean ± SD	57.2 ± 15.0	58.8 ± 10.9
Marriage		
Married	119(71.7%)	166(81.0%)
Education level		
High school at least	82(49.4%)	113(55.1%)
Residence		
Local Kaohsiung	115(69.3%)	140(68.3%)
Neighboring Pingtung County	36(21.7%)	42(20.5%)
Neighboring Tainan County	6(3.6%)	6(2.9%)
Comorbidity		
Hypertension	42(25.3%)	52(25.4%)
Diabetes	9(5.4%)	19(9.3%)
Two or more chronic diseases	25(15.1%)	35(17.1%)
Performance status		
ECOG≤2	162 (97.6%)	195 (95.1%)
Primary tumor site		
Lung	59 (35.5%)	55 (26.8%)
Brain	67 (40.4%)	2 (9.8%)
Target for treatment		
Primary	78 (47.0%)	40 (19.5%)
Recurrent	16 (9.6%)	98 (47.8%)
Metastatic	72 (43.4%)	67 (32.7%)
Treatment site		
Brain	140 (84.3%)	31 (15.1%)
Head and neck	5 (3.0%)	70 (34.1%)
Lung	11 (6.6%)	41 (20.0%)
Admission		
Out-patient	152 (91.6%)	103(50.4%)
Hospitalized	14 (8.4%)	102 (49.8%)

Abbreviations: SD=Standard deviation, ECOG=Eastern Cooperative Oncology Group

Table 2

The performance status of patients who underwent CyberKnife® radiotherapy.

ECOG performance status	Patients (n=371)
0	32 (8.6%)
1	225 (60.7%)
2	100 (27.0%)
3	14 (3.8%)

ECOG = Eastern Cooperative Oncology Group.

Table 3

The treatment targets in CyberKnife® radiotherapy.

Treatment target	Patients (n=371)
Primary tumor	118 (31.8%)
Recurrent tumor	114 (30.7%)
Metastatic tumor	139 (37.5%)

fractions, most patients underwent treatment every other day (n = 189, 50.9%), 126 patients were treated in a single shot (34.0%), and 56 patients underwent treatment for several consecutive days (15.1%). The mean daily fraction sizes for the patients undergoing radiotherapy 1, 2–5, and ≥6 fractions were 16.54 ± 3.43 Gy, 8.33 ± 1.76 Gy, and 5.03 ± 1.94 Gy, respectively. In total, 361 patients (93.7%) completed the CyberKnife® radiotherapy.

A survival analysis revealed that the 1-year and 2-year overall survival was 67.1% and 56.3%, respectively (Fig. 1A). Furthermore, the 1-year and 2-year disease-free survival was 36.1% and 6.3%, respectively (Fig. 1B). Patient survival according to the primary tumor is illustrated in Fig. 2B. The patients with brain tumors had the highest survival rate (SR), with a 1-year and 2-year SR of 96.8% and 88.4%, respectively. The patients with lung tumors had a 1-year and 2-year SR of 67.9% and 60.0%, respectively, while the patients with head and neck tumors had a 1-year and 2-year SR of 32.0% and 28.4%, respectively. The log-rank test results suggested statistical significance ($P < .001$). Regarding the SR by treatment target, the 1-year SR of patients with primary tumors, those with metastatic tumors, and those with locally recurrent tumors was 91.7%, 46.5%, and 64.3%, respectively. The log-rank test results suggested statistical significance (p < 0.001) (Fig. 2B). An analysis of the relationship between the treatment site and patient SRs indicated that the patients treated in the brain had the highest SR (1-year SR of 79.9%), followed by those treated in the head and neck (1-year SR of 69.9%; $P <$ .001) (Fig. 2C). In terms of ECOG PS, the patients with an ECOG ≤1 had a higher SR (1-year SR of 79.8%) than those with an ECOG ≥2 (1-year survival rate of 39.5%). Fig. 3A shows the survival curves with P values <.001. The outpatients had a higher SR than those who were hospitalized (1-year SR of 79.9% vs. 41.4%, $P < .001$) (Fig. 3B). The patients who were prescribed steroids during the treatment period had a higher SR than those who were not (1-year SR of 74.5% vs. 61.7%, $P = .036$) (Fig. 3C). Moreover, the patients who completed their treatment had a higher SR than those who did not (1-year SR of 72.9% vs. 52.9%, $P < .001$) (Fig. 3D). The patients whose expenses were approved and covered by the NHI had a higher SR than those who paid out of pocket. Specifically, the NHI group had a 1-year SR of 81.9%, whereas the out-of-pocket group had a 1-year SR of 55.6%. The log-rank test results suggested statistical significance ($P < .001$) (Fig. 4).

Regardless of treatment location, we conducted a multivariate analysis using the following variables: ECOG PS, treatment expense reimbursed by NHI, the primary disease only, hospitalization during treatment, and prescription of steroids. The results are presented in Table 5 and show that, except for steroid prescription, all factors were independent for survival after the CyberKnife® treatment, with ECOG PS the most significant independent factor for survival. The patients with an ECOG ≥2 presented a hazard ratio of 3.228 for mortality compared with the patients with an ECOG ≤1 after the CyberKnife® treatment. The second most significant independent factor was disease status; the patients with metastatic and recurrent tumors had a

Table 4

The treatment sites of CyberKnife® radiotherapy.

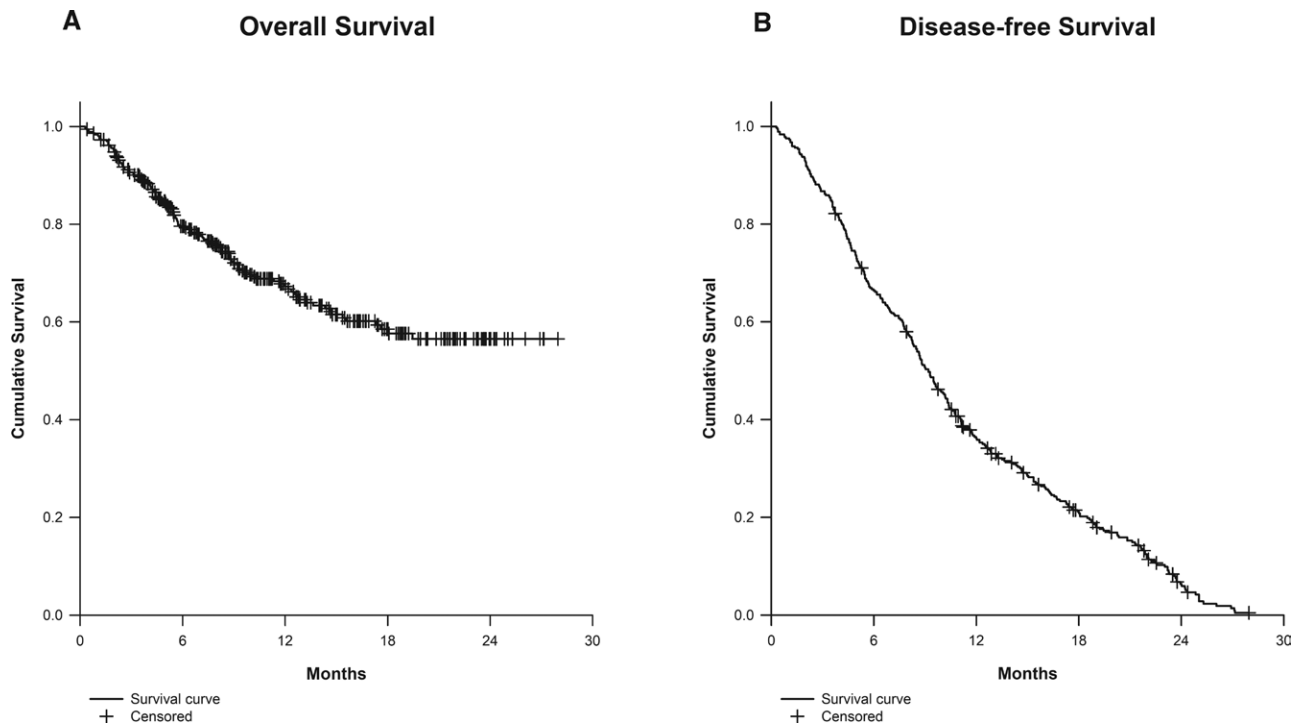| Treatment site	Patients (n=371)
Brain	171 (46.1%)
Head & neck	75 (20.2%)
Lung	52 (14.0%)
Regional lymph node	20 (5.4%)
Prostate	13 (3.5%)
Liver	12 (3.2%)
Distant lymph node	8 (2.2%)
Spine	6 (1.6%)
Eye	4 (1.1%)
Cervix	2 (0.5%)
Pancreases	2 (0.5%)
Adrenal gland	2 (0.5%)
Vaginal	1 (0.3%)
Rib	1 (0.3%)
Bone	1 (0.3%)
Rectum	1 (0.3%)

Figure 1. (A) Overall survival and (B) Disease-free survival for all patients who underwent CyberKnife® radiotherapy.
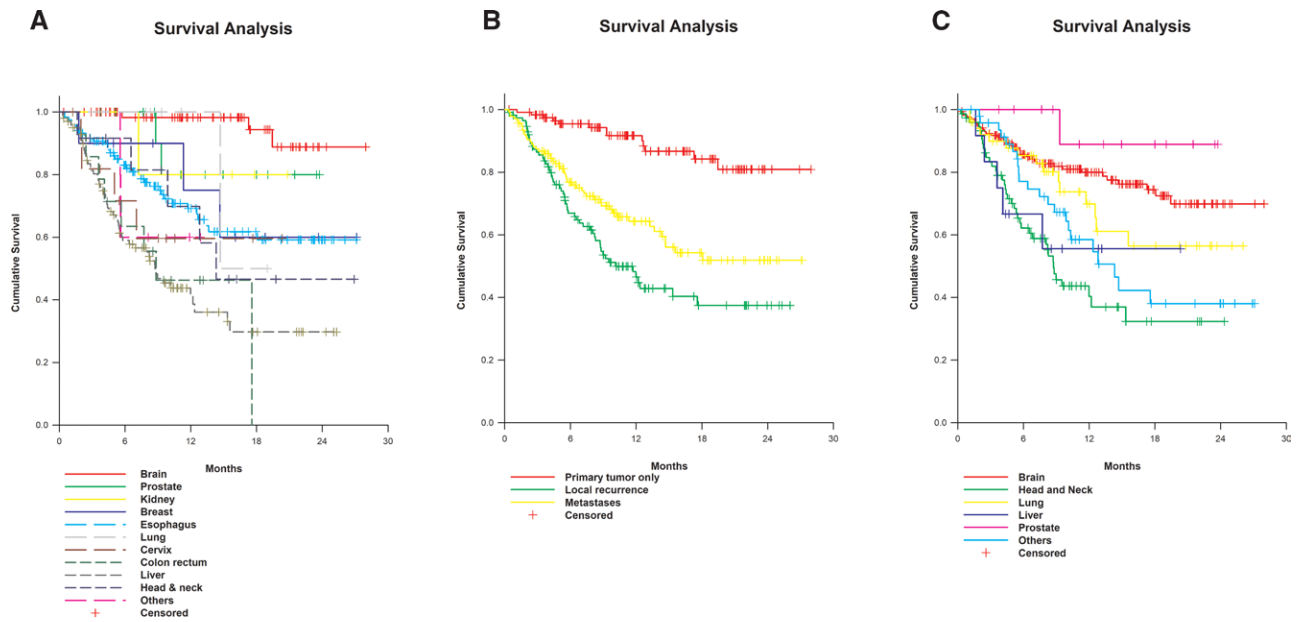

Figure 2. Survival function according to the (A) primary tumors, (B)treatment targets, and (C) treatment sites of the patients who underwent CyberKnife® treatment.

hazard ratio of 2.711 for mortality compared with those with only primary tumors after CyberKnife® treatment.

4. Discussion

Although radiation therapy mainly treats malignant diseases, it is an effective treatment for benign tumors and vascular mal-formation. The indicated criteria of CyberKnife® treatment for NHI reimbursement are described in Supplementary Digital Content 1, http://links.lww.com/MD/G982. The criteria by NHI for reimbursement should also be recognized indications for

CyberKnife® treatment. According to the content of the criteria of CyberKnife® treatment that can be reimbursed by NHI, the most detailed is the treatment of the brain. It's no wonder that most patients in this study were about the brain regardless of the primary disease or treatment site. However, for the machine characteristics of precision and accuracy, some clinical conditions still do not meet NHI criteria and are suitable for CyberKnife® treatment after a physician's evaluation. The patient could also pay by himself for treatment. In Table 1, males (73.2% vs. 49.4%) and hospitalization (49.8% vs. 8.4%) account for a more prominent proportion of patients who pay
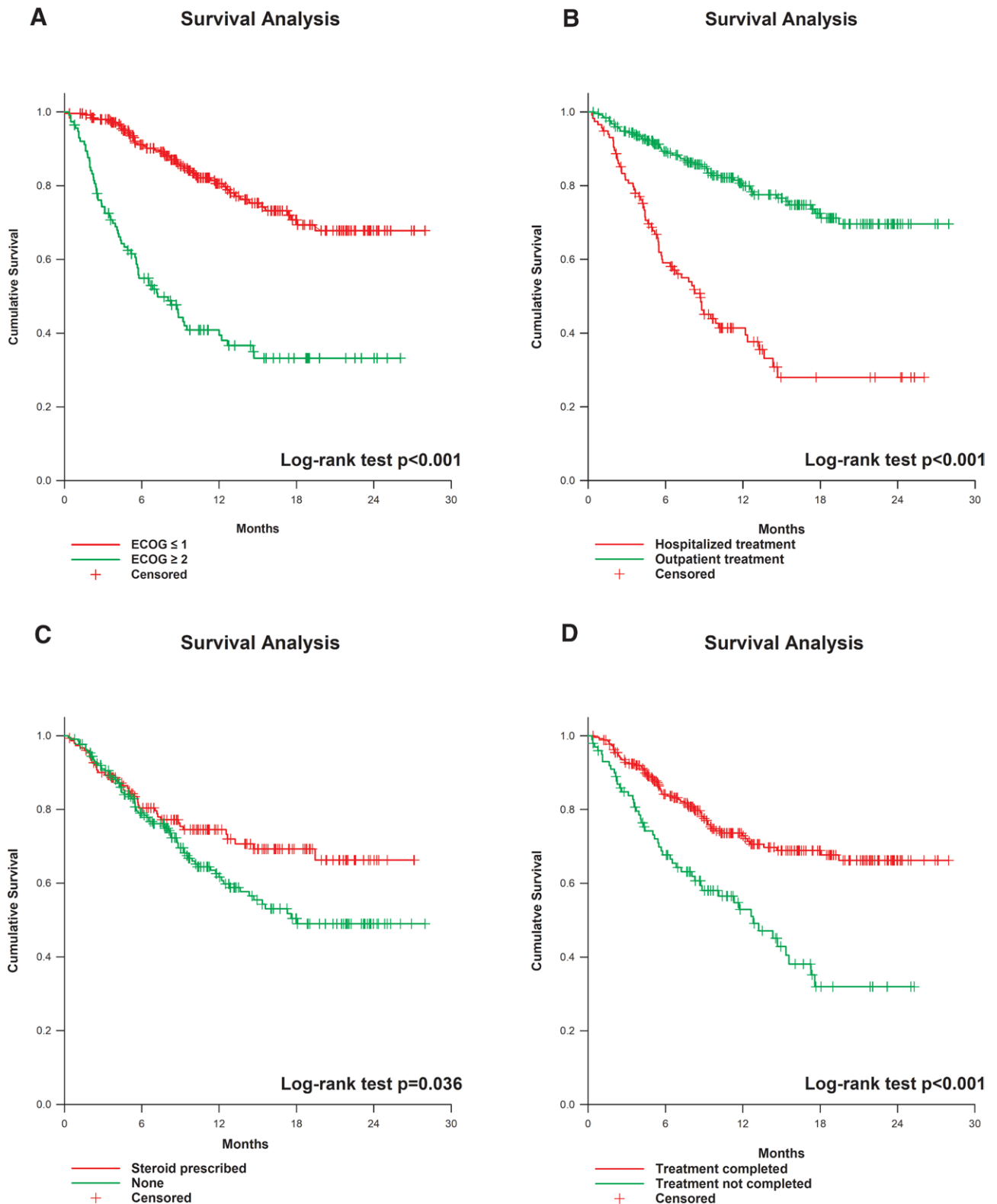
Figure 3. Survival function for patients who underwent CyberKnife® radiotherapy by (A) the performance status ECOG ≤ 1 or not, (B) hospitalized vs. outpatient, steroid prescribed vs. none, and treatment completed or not.

out-of-pocket than those reimbursed by NHI. The large proportion of males in the out-of-pocket group may be related to patriarchal preference in Asian societies and traditionally male control of major economic decisions. The higher proportion of hospitalized patients who underwent CyberKnife® radiotherapy out-of-pocket suggested being since the disease had already

impacted the patient and immediate treatment was needed. Whether the treatment is out-of-pocket or reimbursed by insurance, its rationality and benefits should be considered seriously.

For comparing treatment outcomes, survival is the most intuitive metric to assess the effect of cancer treatment. Because the primary diseases of this study were diverse, and the clinical
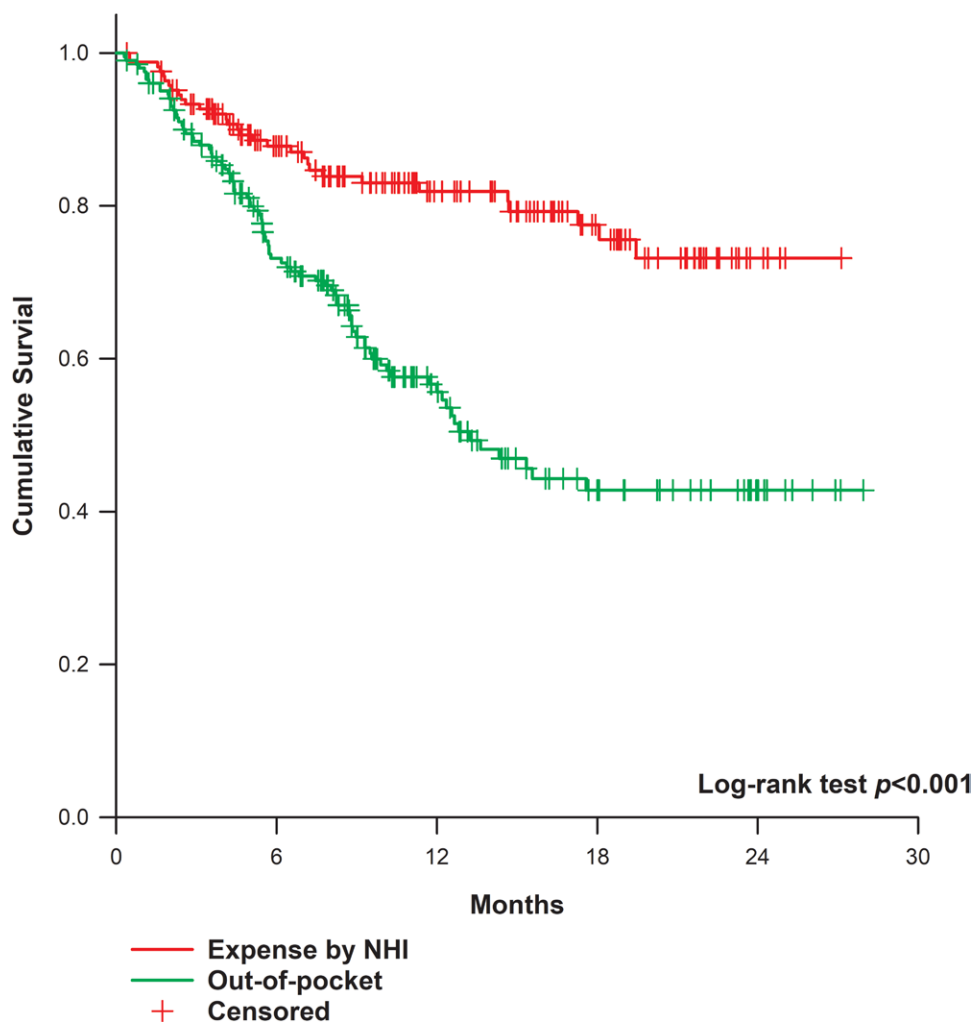
Survival Analysis

Figure 4. Survival function for the CyberKnife® treatment expense (NHI reimbursement vs. out-of-pocket).

status of patients was also different, survival should be the most suitable index for comparing the results after CyberKnife® treatment. The patients included in this study could be treated for primary, metastatic, or locally recurrent tumors depending on their disease status. The results indicated that the patients with primary tumors had the most favorable SR, followed by those with metastatic tumors and local recurrences ($P < .001$). According to the treatment location, the most favorable SR was for the patients undergoing brain treatment, followed in descending order by those undergoing lung and head, and neck treatment ($P < .001$). Numerous studies have indicated that the CyberKnife® system can also be helpful for recurrent and metastatic tumors, such as liver and lung metastases and recurrent head and neck tumors.[5–7] Treatments for metastatic or recurrent tumors aim to slow the disease's progress, extend overall survival, and improve patients' quality of life. For patients with metastatic cancer, a poor PS, or advanced age, in particular, CyberKnife® reduced the difficulty in traveling to and from the hospital thanks to its hypofractionated capability in radiotherapy.[8] Palliative radiotherapy can alleviate patients' symptoms and has no severe side effects, particularly for patients with pain, difficulty breathing, and increased intracranial pressure. Such an intervention can even extend the SR of patients with metastatic

cancer.[9] CyberKnife® radiotherapy is an effective and noninvasive intervention for curative and palliative treatment.

This study revealed that ECOG PS, NHI reimbursement status, location of primary tumors, and outpatient treatment were independent factors for patients' SR after CyberKnife® radiotherapy. Among these factors, ECOG PS was the most significant. The patients with an ECOG 0–1 had 3.228 times the relative SR of those with an ECOG >2. The second most salient factor was disease status; the patients with primary tumors presented 2.711 times the relative SR of the patients with metastatic and recurrent tumors. A relevant study indicated that the PS (measured using a KPS ≥70) and disease status were the most critical factors for selecting the treatment modality for brain metastases.[10] Bollen et al. conducted a systematic review of the prognostic factors related to the SR of patients with spinal bone metastases. They concluded that primary tumors and PS were the 2 most relevant prognostic factors for survival,[11] consistent with our study. Systematic examination and clinical evaluation are critical for cancer treatment. Several standard scores for assessing a patient's performance include ECOG, World Health Organization (WHO), and Karnofsky's performance status (KPS) scores. No matter what kind of PS indicates a patient's quality of life and can serve as indicators of SR and prognosis after treatment.[12,13]

Table 5

Cox regression for survival after CyberKnife® radiotherapy.

Factors	Hazard Ratio	95% confidence interval	P value
ECOG			
≥2 vs. ≤1	3.228	2.204–4.792	<.001*
Expense			
Out-of-pocket vs. NHI-funded	1.666	1.032–2.688	.037*
Disease status			
Local recurrence and metastases vs. primary tumor only	2.711	1.478–4.971	.001*
Hospitalization			
Hospitalized vs. outpatient	1.981	1.279–3.068	.002*
Steroid Prescription			
None vs. prescribed	0.870	0.582–1.302	.500

ECOG = Eastern Cooperative Oncology Group.
*$P < .05$, statically significant.

In the present study, 116 inpatients (31.3%) and 255 outpatients (68.7%) underwent treatment. The SR of the patients who did not stay in the hospital during their treatment was higher than that of patients who did stay ($P < .001$). The hospitalized patients typically had more severe diseases than the outpatients, and their PSs were poorer. Tsai et al. conducted a study on hospitalized patients with cancer and found that most had stage IV disease in terms of disease progression, and more than half had metastasis. Patients from the oncology department mostly underwent surgery or those with multiple metastases. These patients generally have a medium quality of life, which is not ideal, and poorer physiological and psychological status.[14] Therefore, the present study inferred that the disease status of the hospitalized patients was generally more severe than that of the outpatients, with poorer PS, which affected their treatment SR after CyberKnife® radiotherapy. Overall, the patients' PS and disease status significantly impact the treatment outcome of CyberKnife®, and not every patient is suitable for CyberKnife® radiotherapy. The treatment response and effectiveness need to be considered seriously for such a high-cost treatment option. Particularly under the NHI system, patients whose treatment is not approved by the system have to pay out-of-pocket if they want the procedure. More information should be provided for patients to make decisions, of course.

Insurance status has an impact on survival, especially for cancer patients. A study of cancer survival by health insurance status in California reflected a lack of improvement in survival for patients with no insurance.[15] Insured laryngeal cancer patients had been reported to have prolonged overall survival and disease-specific survival compared to uninsured patients.[16] Lung cancer patients with good insurance status had better survival rates than those with poor insurance. An association was significant even after 10 years. High reimbursement insurance status can lead to the improvement of long-term cancer prognosis.[17] The policy of expanding health insurance reimbursement might have been associated with a significant increase in survival among cancer patients by ensuring access to health care. It is believed that eliminating delayed treatment might reduce medical expenses and improve health outcomes.[18] Indeed, the literature indicates that insurance status will affect the survival rate, but under national insurance, whether the treatment can be reimbursed after prereview has an unknown impact on survival. In this study, NHI reimbursement was an independent factor affecting the SR after CyberKnife® radiotherapy. Our study sample comprised 205 patients (55.3%) who had undergone CyberKnife® treatment at their own expense and 166 (44.7%) who had their expenses covered by the NHI after prereview. The NHI reimbursement group had a more satisfactory SR than the out-of-pocket group ($P < .001$). NHI-approved indications are mostly primary diseases found in patients with relatively favorable PS. Studies in the literature have verified that, for benign brain tumors[19–21] and early-stage tumors,[22] CyberKnife® treatment can improve the local control rate. In clinical observations, NHI-covered indications have indeed exhibited relatively satisfactory SRs.

Taiwan established the NHI Committee to enable payers, medical service providers, governmental representatives, scholars, and experts to discuss NHI financial affairs and make relevant decisions. The committee mainly comprises scholars and professionals and is responsible for reviewing the scope of NHI reimbursement. Thus, all NHI-covered indications have passed a professional review, verifying that the treatment in question can effectively improve SRs and disease control. According to the results of this report, the patients approved by the treatment indications set by the NHI bureau's prereview system indeed had a higher SR than those who were not approved. The prereview mechanism of the NHI can screen out patients suitable for CyberKnife® radiotherapy to achieve the reasonable use of medical resources.

Continual progress in radiotherapy has enhanced the precision and expanded the scope of radiosurgery indications. CyberKnife® achieves remarkable therapeutic effects but has high costs in terms of equipment and treatment. The effectiveness of high cost-treatment, such as CyberKnife® radiotherapy, is critical. A careful review must be conducted in advance when selecting patients to undergo CyberKnife® radiotherapy. According to our result, the patient's performance status was the most significant factor for survival after CyberKnife® radiotherapy. In addition to the patients' characteristics, the treatment reimbursement approved by the NHI prereview for the treatment indications had a higher survival rate than the out-of-pocket. However, it does not imply that financial approval changes the survival of patients. It should be the patients indicated for CyberKnife® radiotherapy after clinical evaluation by a physician. Were the survivals of the patients who had been approved after prereview for insurance reimbursement and met the payment criteria better? The answer should be yes, according to our results. This implies that the criteria for CyberKnife® radiotherapy by NHI are appropriate, and the prereview process will not significantly affect the patient's treatment outcome.

The limitation of this study is that the population for CyberKnife® was only in one institution. However, at the time machine was installed, there were only 2 CyberKnife® located in the north and south of Taiwan. The outcome of one institute may not represent national results, but our results should be informative. Indeed, categorizing whether patients paid out-of-pocket or not is crude. Matched case-control study should be a way to get relatively correct results. However, the treatment cost of CyberKnife® is high, and the diseases indicated for treatment are diverse. The matched number and statistical power are not satisfied after matched case study. This study aimed to disclose a sketch of patients for CyberKnife® treatment and examine the reasons for the NHI prereview process. Based on the currently available data, such an analysis is the best we can do to provide informative results. Indeed, if more data are available in the future, a matched case-control analysis can be performed and provide more accurate results. Examination after a larger number of samples available should be performed to validate this study in the future. As for whether the results of this study can be inferred for other high-priced medical instruments, more research is needed to clarify.

In conclusion, the NHI bureau in Taiwan devised a prereview system to reimburse high-priced treatments, such as CyberKnife® radiotherapy. Under such a system, the survival of patients who were not approved for reimbursement by NHI prereview at their own expense was inferior to approved patients. Therefore, a careful evaluation must be conducted before treatment to ensure the benefit. The requirement for re-review to reimburse expensive treatment is not an unreasonable system.

Acknowledgments

Author contributions

Conception and design of the study: YHH and YJH; acquisition of data: YHH, MYH, CJH, and HHK; analysis and interpretation of data: YHH, MYH, and YJH; drafting, revising, and proofing manuscript: YHH, MYH, CJH, HHK, and YJH.

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