Cost-effectiveness analysis of pembrolizumab plus chemotherapy for previously untreated metastatic non-small cell lung cancer in the USA

Xiaohui Zeng,1,2 Xiaomin Wan,2,3 Liubao Peng,2,3 Ye Peng,2,3 Fang Ma,4 Qiao Liu,2,3 Chongqing Tan 1,2

ABSTRACT

Objectives Evaluating the cost-effectiveness of pembrolizumab plus standard chemotherapy in the first-line setting for patients with metastatic non-small cell lung cancer (NSCLC) from the US payer perspective.

Design A Markov model was constructed to analyse the cost-effectiveness of pembrolizumab plus chemotherapy in the first-line treatment of metastatic NSCLC. Health outcomes were estimated in quality-adjusted life-years (QALYs). The cost information was from Medicare in 2018. One-way and probabilistic sensitivity analyses examined the impact of uncertainty and assumptions on the results.

Setting The US payer perspective.

Participants A hypothetical US cohort of patients with previously untreated metastatic nonsquamous NSCLC without EGFR or ALK mutations.

Interventions Pembrolizumab plus chemotherapy versus chemotherapy.

Primary outcome measures Costs, QALYs, incremental cost-effectiveness ratio (ICER) of pembrolizumab plus chemotherapy expressed as cost per QALY gained compared with chemotherapy.

Results The base case analysis demonstrated that pembrolizumab plus chemotherapy provided an additional 0.78 QALYs at incremental cost of $151,409, resulting in an ICER of $194,372/QALY. The cost-utility of pembrolizumab plus chemotherapy was $149,680/QALY in all of our univariable and probabilistic sensitivity analyses.

Conclusions Pembrolizumab in addition to chemotherapy provides modest incremental benefit at high incremental cost per QALY for the treatment of previously untreated metastatic NSCLC.

INTRODUCTION

Globally, lung cancer had an incidence rate of 27.4 per 100,000 and a mortality rate of 23.1 per 100,000 in 2018,1 and non-small cell lung cancer (NSCLC) accounted for the vast majority of these cases.2 Multiple drug regimens are available for the treatment of advanced NSCLC, including platinum-based combination chemotherapy, anaplastic lymphoma kinase (ALK) tyrosine kinase inhibitor (TKI), epidermal growth factor receptor (EGFR) TKI and immune checkpoint inhibitors.3 Immune checkpoint inhibitors showed higher efficacy and less toxicity compared with other therapies.4

A new era of treating advanced NSCLC is upon us after the emergence of immunosuppressive agents.4 Immune checkpoint inhibitors improve antitumor immunity by inhibiting programmed death 1 (PD-1) receptor or programmed cell death ligand 1 (PD-L1).5–7 Pembrolizumab, a PD-1 inhibitor, was approved by the US Food and Drug Administration (FDA) for treatment of advanced NSCLC in 2015.8,9 The Keynote-189 clinical trial showed pembrolizumab in combination with pemetrexed plus carboplatin or cisplatin could extend progression-free survival (PFS) by 3.9 months for patients with metastatic NSCLC without sensitising ALK or EGFR mutations.10

Although pembrolizumab plus chemotherapy improved survival significantly, the additional cost was notably high. Therefore, it is worth discussing whether pembrolizumab plus chemotherapy is a cost-effective regimen. The goal of this study was to analyse the cost-effectiveness of pembrolizumab plus chemotherapy for previously untreated metastatic NSCLC without ALK or EGFR mutations from the US payer perspective.
distribution, and overall survival (OS) data points were estimated by \( \exp(-\lambda t) \) and \( \exp(-\lambda t) \), respectively, where \( \lambda \) is the scale parameter, \( \gamma \) is the shape parameter and \( t \) is survival time (table 1 near here).

**Costs**

Only direct costs, including the costs of the drug, premedication, administration and management of serious adverse events (AEs) (table 1 near here), were considered in our evaluation. In the PFS state, the cost of the intravenous drug for 3-week cycle was based on the following doses: pembrolizumab 200mg/cycle, pemetrexed 500mg/m\(^2\), cisplatin 75mg/m\(^2\) and carboplatin 400mg/m\(^2\).

The model considered the hospitalisation cost of patients with AE \( \geq \) grade 3, and the incidence rate exceeded 5% because these AEs were of great concern to clinicians. And then the incidence rates of neutropenia and pneumonia from the Keynote-189 trial were used to calculate the cost of AEs treatments.

Based on the Keynote-189 trial, 90.5% of the patients in the pembrolizumab plus chemotherapy group and 46.6% in the placebo plus chemotherapy group received subsequent therapy after disease progression. Among patients in the pembrolizumab plus chemotherapy group, 3% received carboplatin plus pemetrexed, 2.3% received docetaxel plus ramucirumab, 17.8% received docetaxel, 4% received nivolumab and 3.4% received continuation maintenance treatment of pembrolizumab; among patients in the placebo plus chemotherapy group, 1.7% received docetaxel, 7.8% received nivolumab and 38% received crossover treatment with pembrolizumab. Patients who died accrued the cost of terminal care, including hospitalisation, palliative chemotherapy, doctor consultation, laboratory and diagnostic tests, according to the published literature.

The mean value of a body surface area and body weight are 1.84m\(^2\) and 82kg, respectively. The drug costs were taken from the Centers for Medicare and Medicaid Services. Administration costs were calculated according to the Medicare physician fee schedule for 2018. The costs of AEs and end-of-life care were derived from the published literature.

**Outcome measures**

The outcome indicator of the study was QALYs, which is defined by the patient’s life years and health utility. In accordance with the approach of Anna Oh et al., we also considered the disutility of AE. Baseline utility and disutility values were referenced in the published literature (table 1 near here).

**Analysis**

The uncertainty of the parameters was evaluated by one-way sensitivity analysis and probabilistic sensitivity analysis, through the use of tornado diagrams and Monte Carlo simulation, respectively. The beta distribution was applied for the utilities, and the lognormal distribution was applied for the cost. Utilities were varied over their 95% CIs. In general, the upper and lower limits of the

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**Figure 1** State transition diagram. The three circles show three main health states. Patients can transition from ‘progression-free survival’ to ‘disease progression survival’ or ‘death’.
Table 1  Parameters for cost effectiveness model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pembrolizumab</th>
<th>Placebo</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Value</td>
<td>Ranges</td>
</tr>
<tr>
<td>Probabilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFS (Weibull)</td>
<td>0.0448</td>
<td>±25%</td>
</tr>
<tr>
<td>Scale(λ)</td>
<td>1.2675</td>
<td></td>
</tr>
<tr>
<td>OS(exponential)</td>
<td>0.0290</td>
<td></td>
</tr>
<tr>
<td>Costs ($)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pembrolizumab/mg</td>
<td>48.57</td>
<td>±25%</td>
</tr>
<tr>
<td>Pemetrexed/mg</td>
<td>6.75</td>
<td>±25%</td>
</tr>
<tr>
<td>Cisplatin/mg</td>
<td>0.20</td>
<td>±25%</td>
</tr>
<tr>
<td>Carboplatin/mg</td>
<td>0.06</td>
<td>±25%</td>
</tr>
<tr>
<td>Chemotherapy infusion 1 hour</td>
<td>145</td>
<td>±25%</td>
</tr>
<tr>
<td>Chemotherapy infusion additional hour</td>
<td>32</td>
<td>±25%</td>
</tr>
<tr>
<td>Subsequent therapies/cycle</td>
<td>1160</td>
<td>±25%</td>
</tr>
<tr>
<td>End-of-life care</td>
<td>33009</td>
<td>±25%</td>
</tr>
<tr>
<td>AE hospitalisation cost</td>
<td>3538</td>
<td>±50%</td>
</tr>
<tr>
<td>Baseline utilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFS19</td>
<td>0.71</td>
<td>0.67–0.76</td>
</tr>
<tr>
<td>disease progression survival19</td>
<td>0.67</td>
<td>0.59–0.75</td>
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<tr>
<td>Disutilities</td>
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<td></td>
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<tr>
<td>Neutropenia20</td>
<td>0.09</td>
<td>0.060–0.119</td>
</tr>
<tr>
<td>Pneumonia20</td>
<td>0.09</td>
<td>0.059–0.121</td>
</tr>
</tbody>
</table>

AE, adverse effect; OS, overall survival; PFS, progression-free survival.

parameters were taken from the literature, and if otherwise, upper and lower limits of 25% were set. All baseline values and ranges for variables are shown in table 1.

Patient and public involvement
No patients or public were involved in the study.

RESULTS
Base case analysis
Weibull and exponential models used to fit the survival curves from the clinical trial (online supplementary appendix 1), which show that the decision analysis model established in this study can reflect the clinical effects very well. In the base case analysis, the lifetime cost of using pembrolizumab plus chemotherapy was $288 532 compared with $137 123 for placebo plus chemotherapy. When considering effectiveness, the pembrolizumab plus chemotherapy strategy yielded 1.61 QALYs, compared with 0.83 QALYs for the placebo plus chemotherapy strategy. The ICER of pembrolizumab plus chemotherapy was calculated as $194 372/QALY compared with the placebo plus chemotherapy. When pembrolizumab cost $12.05 and $31.38/mg, the ICERS approximated the WTP thresholds of $100 000 and $150 000/QALY, respectively (table 2).

Sensitivity analysis
The tornado diagrams present the results of one-way sensitivity analyses. Obviously, the cost of pembrolizumab, the cost of subsequent treatment in the placebo-combination group and baseline utility values of OS were the most relatively sensitive parameters, and the ICER range was

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Base case model analysis*</th>
</tr>
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<tbody>
<tr>
<td>WTP value, $/QALY</td>
<td>100 000</td>
</tr>
<tr>
<td>Nivolumab cost, $/mg</td>
<td>12.05</td>
</tr>
<tr>
<td>Total cost, $</td>
<td>176 197</td>
</tr>
<tr>
<td>QALYs</td>
<td>1.61</td>
</tr>
<tr>
<td>ICER, $/QALY</td>
<td>99 915</td>
</tr>
</tbody>
</table>

*Only the cost of pembrolizumab was varied.
ICER, incremental cost-effectiveness ratio; QALY, quality-adjusted life-year; WTP, Willingness-to-pay.
from $149,680/QALY to $239,065/QALY (figure 2). The discount rate, the cost of subsequent treatment in the pembrolizumab-combination group, the cost of pemetrexed, the baseline utility value of PFS and the cost of AE management had little impact on the model.

The cost-effectiveness acceptability curve shows the probabilistic sensitivity analysis results of different willingness-to-pay (WTP) thresholds (figure 3). The probability that pembrolizumab combined with chemotherapy is cost-effective increased as WTP increased. The results showed that the probability of pembrolizumab plus chemotherapy being cost-effective was 0% at a WTP threshold of $130,000/QALY. If WTP threshold is $192,000/QALY, the pembrolizumab plus chemotherapy strategy show a 50% chance cost-effectiveness (figure 3).

The results of the subgroup analysis showed that pembrolizumab combined with chemotherapy was the most cost-effective (36%) for patients who had never smoked at a WTP threshold of $100,000. When the WTP threshold was $150,000, the probability of pembrolizumab combined with chemotherapy being cost-effective in the subgroup of never-smoking and female patients was 100% (see online supplementary appendix 2).

**DISCUSSION**

We performed a cost-effectiveness analysis of pembrolizumab in addition to chemotherapy in previously untreated metastatic NSCLC. Based on our model, the ICER for pembrolizumab plus chemotherapy was estimated as $194,372/QALY compared with the placebo plus chemotherapy. The results showed that the probability of pembrolizumab plus chemotherapy being cost-effective was 0% at a WTP threshold of $130,000/QALY.

There are many other studies that have analysed the cost-effectiveness of pembrolizumab for advanced NSCLC in different setting. In the KEYNOTE-024 trial, pembrolizumab demonstrated the incremental survival benefits and better safety profile versus chemotherapy for first-line treatment of PD-L1-positive (≥50%) metastatic NSCLC patients. Based on the KEYNOTE-024 trial, a US-based study found that pembrolizumab was cost-effective, with an ICER of $97,621/QALY, a study by Georgieva et al demonstrated that pembrolizumab monotherapy was cost-effective in the USA but not the UK, a study by Hu et al conducted in the UK demonstrated that pembrolizumab plus chemotherapy was not cost-effective, with an ICER of £86,913/QALY, and a French study found that pembrolizumab appears cost-effective.

Our results differ from the above results may be due to different health systems and costs in different countries, which leads to different cost-effectiveness conclusions. Based on the KEYNOTE-010 trial, a study analysed the cost-effectiveness of pembrolizumab and docetaxel as second-line treatment for PD-L1 positive advanced NSCLC from the US third-party payer perspective. The results showed that the ICER was $168,619/QALY, which was cost-effective at a threshold of three times GDP per capita ($171,660). These data provide reference value for evaluating the total cost of therapy and the value of regimens for advanced NSCLC.
Our one-way sensitivity analysis revealed that the cost of pembrolizumab had a great influence on the results of the study. High drug prices are the result of the monopoly of pharmaceutical companies and restrictions on the negotiating power of the payer.20 This can be addressed by providing more meaningful price negotiation opportunities for payers and providing more evidence of a cost-effectiveness comparison of treatment regimens.26 We can also reduce the cost of administration by using personalised dosing. Recent study has shown that personalised dosing (2 mg/kg) and fixed dosing (200 mg) of pembrolizumab have equivalent efficacy.27 Avoiding drug waste is extremely important in an era of value-based cancer therapy.28 When our study used 2 mg/kg of pembrolizumab based on the average weight of 82 kg, the ICER was reduced to $171 751. We believe that manufacturers are responsible for providing multiple sizes of vials to minimise the chance of wastage.

However, there are few limitations to our study that deserve consideration. First, we used cost parameters provided by Medicare, which may be lower than private insurers.29 Second, the health utility values were taken from other data sources instead of patients who participated in the Keynote 189 trial, which limits the accuracy of our results. Unfortunately, the clinical trial did not report the quality of life. Third, our analysis did not estimate the costs for all AEs in the PFS state, which may lead to underestimation of AEs costs. However, considering the low incidence, we expect the inclusion of all AEs would not change the conclusions of the present analysis. In addition, our model applied sensitivity analysis to a wide variation of these parameters, and it does not affect the results. Fourth, our analysis was based on the Keynote 189 trial, which excluded patients with sensitising EGFR or ALK translocation, because they usually used targeted agents as first-line treatment. However in the real-world setting, these patients with unknown EGFR or ALK translocation were also likely to be received PD-L1 testing and treated with pembrolizumab. Finally, our study directly compared pembrolizumab plus chemotherapy with chemotherapy according to the KEYNOTE-189 trial. Although there are other potential first-line treatments for advanced non-small cell lung cancer, our study did not indirectly compare them because of the lack of convincing trial data and robust head-to-head trial data.

Overall, the combination of pembrolizumab and chemotherapy for patients with metastatic NSCLC that we studied has high incremental cost and modest incremental benefit. New treatment technology for tumour is continuously undergoing development, but the price of tumour drugs is also rising dramatically. Based on our analysis, pembrolizumab offers lower value at current cost. The provision of cost-effective care requires new pricing and payment systems to support. The process for approving new drugs and the process of incorporating them into the guidelines must balance costs and benefits, and our research can offer decision-making information for this purpose.

**Contributors** Study concepts and design: CT. Clinical program: FM. Analysis and interpretation of the data: LP, YY, QL. The drafting and revising of the paper: XZ and XW; Final approval of manuscript: All authors; all authors agree to be accountable for all aspects of the work.

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**Competing interests** None declared.

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