Cost-effectiveness analysis of adjuvant treatment for resected pancreatic cancer in China based on the ESPAC-4 trial

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Background: The effectiveness of gemcitabine plus capecitabine compared with gemcitabine monotherapy for resected pancreatic cancer has been evaluated in the ESPAC-4 trial. We aimed to assess the cost-effectiveness of these adjuvant regimens on resected pancreatic cancer.

Methods: A Markov model was established to simulate the disease process of resected pancreatic cancer (relapse-free survival, progressive disease, and death). The efficacy and toxicity profiles were collected from the ESPAC-4 trial. Transition probabilities were calculated based on survival in each group. Cost data were calculated from the perspective of the Chinese healthcare payer. The primary endpoint in the analysis was the incremental cost-effectiveness ratio (ICER), and model uncertainties were explored by one-way sensitivity analysis and probabilistic sensitivity analysis.

Results: Our results demonstrated that gemcitabine monotherapy cost $36,028.45 and yielded a survival of 1.02 quality-adjusted life year (QALY), while gemcitabine plus capecitabine cost $46,095.05 and yielded a survival of 1.23 QALY. Therefore, the incremental cost-effectiveness ratio of gemcitabine plus capecitabine vs gemcitabine monotherapy was $45,191.23 which surpassed the willingness-to-pay threshold of $29,291.42 per QALY in China.

Conclusion: The gemcitabine monotherapy regimen is more cost-effective compared with gemcitabine plus capecitabine regimen for the patients with postoperative pancreatic cancer from the Chinese societal perspective.

Keywords: cost-effectiveness, Markov model, gemcitabine, capecitabine, resected pancreatic cancer

Introduction
Pancreatic cancer is a common and highly fatal cancer, with a poor prognosis.1 In pancreatic cancer patients a 5-year survival rate is only 8%, even though there has been a gradual increase in survival for most cancers over the decades.2 More than 80% of patients with pancreatic cancer are asymptomatic and exhibit unresectable advanced pancreatic cancer at diagnosis.3 Only 20% of patients are eligible for initial resection.4 However, after radical resection, most patients will experience recurrence within 2 years.5,6 Surgical resection with adjuvant chemotherapy, with either 5-fluorouracil plus folinic acid or gemcitabine, has increased the 5-year survival rate to ~20%.7–11 Recently, several studies indicated that adjuvant chemotherapy was an effective means for resected pancreatic patients to obtain long-term survival and it is steadily accepted as the established standard of care.8–16

Gemcitabine had been associated with significant improvement in disease-free survival (DFS) and overall survival (OS) in postoperative pancreatic patients com-
pared with placebo cohort (median DFS: 13.4 months vs 6.9 months; median OS: 22.8 months vs 20.2 months).\textsuperscript{5,17} The combination of gemcitabine and capecitabine has synergistic effect on thymidylate synthase involved in normal DNA synthesis.\textsuperscript{18} Moreover, previous clinical trials have demonstrated this combination produced a better tumor response with well tolerated adverse effects compared with monotherapy in patients with advanced pancreatic cancer.\textsuperscript{19,20}

The European study group for pancreatic cancer (ESPAC-IV) trial was performed to evaluate efficacy and safety of gemcitabine plus capecitabine compared with gemcitabine monotherapy for postoperative pancreatic cancer. The results revealed that the gemcitabine plus capecitabine regimen significantly improved median overall survival (OS) and median relapse-free survival (RFS) compared with gemcitabine (28.0 months vs 25.5 months, \(P=0.032\); 13.9 months vs 13.1 months, \(P=0.082\)). Grade 3–4 adverse events, neutropenia, white blood cell count decrease, and hand-foot syndrome were frequently reported in the gemcitabine plus capecitabine cohort (38%, 10%, 7%), whereas neutropenia, white blood cell count decrease, infection and infestations were significantly greater in the gemcitabine monotherapy cohort (24%, 8%, 7%). Thus, the combination of the gemcitabine and capecitabine regimen seemed to be a more effective option for the treatment of resected pancreatic cancer.\textsuperscript{18}

Even though gemcitabine plus capecitabine regimen have proven to have a better clinical response when compared with gemcitabine monotherapy, they have not been directly compared in terms of being cost effective. Taking cost-effectiveness into consideration is crucial for clinicians to make an optimal decision, as well as from a social perspective. Herein, we performed a Markov model to evaluate the cost-effectiveness of gemcitabine plus capecitabine compared with gemcitabine monotherapy for resected pancreatic cancer from the perspective of a Chinese society.

Materials and methods

Patients and regimens

The clinical data for this model was derived from the ESPAC-IV trial, a multicenter, open-label, randomized, phase III trial conducted in 92 hospitals in England, Scotland, Wales, Germany, France, and Sweden.\textsuperscript{18} The inclusion criteria were patients aged 18 years or older who had undergone complete resection for pancreatic cancer.\textsuperscript{18} The eligible patients were randomly assigned within 12 weeks of resection to receive 6 cycles of either 1000 mg/m\textsuperscript{2} gemcitabine alone, administered once a week for 3 of every 4 weeks cycle, or with 1660 mg/m\textsuperscript{2} oral capecitabine administered for 21 days followed by a 7 day rest per cycle.\textsuperscript{18} Laboratory tests, clinical symptoms, tumor markers, chest radiographs and abdominal CT were assessed based on the protocol of ESPAC-4 trial.\textsuperscript{18} The median RFS was 13.9 months in gemcitabine plus capecitabine cohort, and 13.1 months in gemcitabine monotherapy cohort The median overall survival (OS) of gemcitabine plus capecitabine and gemcitabine monotherapy was 28.0 and 25.5 months, respectively.\textsuperscript{18} The other primary input clinical efficacy parameters are shown in (Table 1).

Model structure

A Markov model was performed with TreeAge Pro 2011 (TreeAge Software, Inc., Williamstown, MA, USA) to simulate the disease process of resected pancreatic cancer and compare the cost-effectiveness of 2 strategies based on the ESPAC-4 trials. The decision model structure comprised 3 mutually exclusive states including RFS, progressive disease (PD), and death (Figure 1). The patients could shift to a different state at the end of each cycle in the Markov model, according to the transition probabilities calculated by the 5-year RFS rate; and 5-year OS rate (Table 1), and costs and benefits were discounted to present values at 3% for 1 year.\textsuperscript{21}

The model cycle length was 1 month, and the time horizon was 10 years. Monthly transition probabilities of health states were calculated by the following formula: \(r=[1-ln(1-P_1)]/t\), \(P_1=\exp(-ru)\), \(r\): instantaneous rate; \(P_1\): cumulative probability at time \(t\) (5 years), \(u\): model cycle length, \(P_2\): Monthly transition probabilities.\textsuperscript{22,23}

Cost estimate

Total costs in our analysis consisted of direct medical costs and societal costs. Cost of drugs and tests were derived from the 2018 fee standards of West China Hospital, Sichuan University. The median relative dose intensity (RDI) of the RFS state drugs in gemcitabine group and gemcitabine plus capecitabine were 83%, 78%, respectively.\textsuperscript{18} Direct medical costs included drugs, tests, inpatient fees and treatments for grade 3–4 AEs. The grade 3–4 AEs rates sourced from the trials were used to calculate the AE-related costs (Table 1), whereas societal costs consisted of travel fees and time costs (absenteeism fees), and travel costs were assessed at $10.20 per patient each trip to the hospital in Sichuan, China, in 2016.\textsuperscript{24} Time costs were estimated at $35.73 per day based on the average monthly salary in China in 2017.\textsuperscript{24} Travel costs and time costs were derived from the average length inpatient hospitalization of 2 times per month, 3 days each time and outpatient visits of 2 times per month. For the cost of PD, in patients chiefly treated with platinum-based chemotherapy
Table 1 Clinical efficacy and adverse events of gemcitabine plus capecitabine and gemcitabine monotherapy

<table>
<thead>
<tr>
<th>Variable</th>
<th>Base-case value</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clinical efficacy, months (95%CI)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median OS (m)</td>
<td>25.5 (22.7–27.9)</td>
<td>18</td>
</tr>
<tr>
<td>Median RFS (m)</td>
<td>13.1 (11.6–15.3)</td>
<td>18</td>
</tr>
<tr>
<td>5-year OS rate</td>
<td>16.3% (10.2–23.7)</td>
<td>18</td>
</tr>
<tr>
<td>5-year RFS</td>
<td>11.9% (7.8–16.9)</td>
<td>18</td>
</tr>
<tr>
<td><strong>Probability of grade 3/4 AEs, %</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anemia</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>Fatigue</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>Fever</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>Infection</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>Lymphocyte count decreased</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Neutropenia</td>
<td>24</td>
<td>18</td>
</tr>
<tr>
<td>Hand-foot syndrome</td>
<td>0</td>
<td>18</td>
</tr>
<tr>
<td>Thrombocytopenia</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>Thromboembolic events</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>White blood cell count decreased</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>Acute kidney injury</td>
<td>1</td>
<td>18</td>
</tr>
</tbody>
</table>

**Abbreviations:** AEs, adverse events; GEM, gemcitabine; GEMCAP, gemcitabine plus capecitabine; OS, overall survival; RFS, relapse-free survival.

Figure 1 Markov model for postoperative pancreatic cancer.

**Notes:** Markov model for resected pancreatic cancer. A Markov model comprising 3 health states (relapse-free survival, PD and death) was built.

**Abbreviations:** GEM, gemcitabine; GEMCAP, gemcitabine plus capecitabine; PD, progressive disease; RFS, relapse-free survival.
regimens, a weighted cost based on FOLFIRINOX (5-FU, leucovorin, oxaliplatin, irinotecan), GEM-N (gemcitabine, nab-paclitaxel) was assumed per cycle.25,26 The RDIs for these treatments were assumed to be 80%.27 All costs were converted to USD, at an exchange rate of $1 = RMB 6.33, in March 2018.

Effectiveness estimates
Treatment effectiveness was estimated by QALYs. Utility scores of Markov states were based on the previous studies, with 0.85 for RFS state and 0.73 for PD state.28,29

Sensitivity analysis
One-way sensitivity analysis was performed to investigate the impact of variables on the analysis model by varying the necessary parameters within a range of ± 30%. As for probabilistic sensitivity analysis, a Monte Carlo simulation of 1,000 iterations was developed to assess the uncertainty strategies, and the results were presented as cost-effectiveness acceptability curves. According to WHO guidelines, the willingness to pay (WTP) threshold value was 3 times Gross Domestic Product per Capita (GDP) of China in 2017, which was $25,840.88/QALY, ie $2,153.40 per quality-adjusted life month.30

Results
Costs outcomes
The estimated monthly costs of the 2 treatments are briefly presented in (Table 2).

As for the cost for RFS state, the greatest cost was RDI-adjusted drugs ($1,237.01 for gemcitabine and $1,726.15 for gemcitabine plus capecitabine). The inpatient fees, test costs and total societal costs were the same in these 2 groups. Moreover, the grade 3–4 adverse effects related to cost were similar ($41.91 for gemcitabine and $55.67 for gemcitabine plus capecitabine). As for the cost of PD state, the total cost was $2,643.56 for both treatment groups. After running the Markov model to the estimated time horizon, the cumulative costs were $36,028.45 for the gemcitabine group, which was significantly lower than that of $46,095.05 for the gemcitabine plus capecitabine group (Table 3).

Cost-effectiveness
As shown in Table 3, according to the cost analysis and effectiveness analysis described previously, the gemcitabine monotherapy was cheaper, with a cost of $35,322.01/QALY compared with $45,191.23/QALY for the combination of gemcitabine and capecitabine. Gemcitabine plus capecitabine group provided an incremental 0.21 QALYs at an incremental cost of $10,066.60, compared with the gemcitabine group, resulting in the ICER of $47,936.19/QALY, which exceeded the WTP threshold of $25,840.88/QALY.

Sensitivity analysis
The one-way sensitivity analyses are displayed in the tornado diagram (Figure 2). The cost of the PD state in gemcitabine plus capecitabine cohort and the cost of the PD state in the gemcitabine cohort played a vital role in our study. When cost

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### Table 2 Cost and utility scores of gemcitabine plus capecitabine and gemcitabine monotherapy

<table>
<thead>
<tr>
<th>Variable</th>
<th>Base-case value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Costs for RFS state (USD/month)</strong></td>
<td>GEM</td>
</tr>
<tr>
<td>Chemotherapy drugs</td>
<td>1,490.37</td>
</tr>
<tr>
<td>RDI-adjusted drugs</td>
<td>1,237.01</td>
</tr>
<tr>
<td>Inpatient fees</td>
<td>140.23</td>
</tr>
<tr>
<td>Grade 3-4 AEs</td>
<td>41.91</td>
</tr>
<tr>
<td>Test</td>
<td>148.13</td>
</tr>
<tr>
<td><strong>Societal costs (USD/month)</strong></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>214.21</td>
</tr>
<tr>
<td>Travel</td>
<td>40.86</td>
</tr>
<tr>
<td>Total societal costs</td>
<td>255.07</td>
</tr>
<tr>
<td>Total</td>
<td>1,822.35</td>
</tr>
<tr>
<td><strong>Costs for PD state (USD/month)</strong></td>
<td></td>
</tr>
<tr>
<td>Weighted average drugs for PD state</td>
<td>2,764.14</td>
</tr>
<tr>
<td>RDI-adjusted drugs</td>
<td>2,211.31</td>
</tr>
<tr>
<td>Additional cost for PD state</td>
<td>432.25</td>
</tr>
<tr>
<td>Total</td>
<td>2,643.56</td>
</tr>
<tr>
<td><strong>Utility scores</strong></td>
<td></td>
</tr>
<tr>
<td>Utility for RFS state</td>
<td>0.85</td>
</tr>
<tr>
<td>Utility for PD state</td>
<td>0.73</td>
</tr>
</tbody>
</table>

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### Table 3 Results of cost-effectiveness analysis of gemcitabine plus capecitabine and gemcitabine monotherapy

<table>
<thead>
<tr>
<th>Result</th>
<th>Regimen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Costs (USD)</strong></td>
<td></td>
</tr>
<tr>
<td>Costs for the RFS state</td>
<td>GEM</td>
</tr>
<tr>
<td>Costs for the PD state</td>
<td>GEM</td>
</tr>
<tr>
<td>Total</td>
<td>GEM</td>
</tr>
<tr>
<td><strong>Effectiveness QALYs (USD)</strong></td>
<td></td>
</tr>
<tr>
<td>Effectiveness for the PFS state</td>
<td>GEM</td>
</tr>
<tr>
<td>Effectiveness for the PD state</td>
<td>GEM</td>
</tr>
<tr>
<td>Total effectiveness</td>
<td>GEM</td>
</tr>
<tr>
<td>C/E ratio (USD/QALY)</td>
<td>GEM</td>
</tr>
<tr>
<td>ICER for GEMCAP VS. (GEM USD/QALY)</td>
<td>GEM</td>
</tr>
</tbody>
</table>

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**Abbreviations:** AE, adverse event; GEM, gemcitabine; GEMCAP, gemcitabine plus capecitabine; PD, progressive disease; RDI, relative dose intensity; RFS, relapse-free survival.
of the PD state in the gemcitabine plus capecitabine cohort varied from $1,850.49 to $3,436.63, the ICER increased from $29,295.30 to $45,656.02 per QALY. If the cost of PD state in gemcitabine group changed from $1,850.49 to $3,436.63, the ICER rose from $22,593.65 to $35,989.21 per QALY. Nevertheless, the cost of test and cost of grade 3–4 AEs in these 2 strategies had a slight impact on the model. The result of the Monte Carlo simulation of 1,000 patients showed that the mean cost and effectiveness gained were: $46,300.77 ± 741.49 and 1.23 ± 0.02 QALY for gemcitabine plus capecitabine group, while $36,243.69 ± 652.05 and 1.03 ± 0.02 QALY for gemcitabine group. The probabilistic sensitivity analysis indicated nearly 100% probability of gemcitabine and 0% probability of gemcitabine plus capecitabine being a cost-effective strategy, as the WTP value was $2,153.40/QALM. (Figure 3)

**Discussion**

Pancreatic cancer is a seriously lethal disease, and mortality rate closely coincides with incidence. After resection, chemotherapy with fluorouracil or gemcitabine significantly prolongs OS and reduces the incidence of relapse. However, a significant burden is placed on patients during the adjuvant therapy process for resected pancreatic cancer. An economic assessment of postoperative adjuvant regimens is vital to keep the balance between clinical benefits and health care cost, especially in developing countries such as resource-limited China. Therefore, we established a Chinese cost-effective analysis of gemcitabine plus capecitabine vs gemcitabine alone for resected pancreatic cancer, which is the first analysis of postoperative pancreatic cancer adjuvant strategies from the efficacy and cost-effectiveness perspective.

According to our analysis, gemcitabine plus capecitabine cohort cost $2,325.25 per month which was higher than gemcitabine alone $1,822.35 for the RFS state. The chemotherapy drugs, test, and inpatient fees costs contributed most to the total costs of different treatment groups. Our one-way sensitivity analyses indicated that the key driver of the ICER of gemcitabine plus gemcitabine vs gemcitabine alone was the cost of the PD state in both cohorts. Gemcitabine plus capecitabine group offered an incremental 0.21 QALY at an incremental cost of $10,066.60, compared with the gemcitabine group.
regimen. Incremental cost-utility ratio ($7082.68 than gemcitabine alone$0.154 QAL Ys and € that paclitaxel ablumin plus gemcitabine regimen offered
treatment, except in metastatic background. A study reported
pancreatic cancer to compare the standard adjuvant treat-
Chinese social perspective.

Italian Medicines Agency.32 Moreover, a pharmacological
effective regimen for metastatic pancreatic cancer by the
bound paclitaxel plus gemcitabine can be considered a cost-
breimbursing oncological drugs, which means that albumin-
Italian Medicines Agency (INHS) during 2010–2013 for
than the informal threshold value of 
€87,330 adopted by the
resulting in the ICER of $47,936.19/QALY. The WTP threshold
of $25,840.88/QALY in our model, which is triple the per
capita gross domestic product of China.31 In other words,
the ICER of gemcitabine plus capecitabine vs gemcitabine
monotherapy dramatically surpassed the general WTP thresh-
old in China, even though the gemcitabine plus capecitabine
regimen showed better clinical response in ESPAC-4 trials.
Thus, gemcitabine plus capecitabine is not an optimal cost-
effective regimen for postoperative pancreatic cancer from
Chinese social perspective.

So far, there has been no economic evaluation for resected
pancreatic cancer to compare the standard adjuvant treat-
ment, except in metastatic background. A study reported
that paclitaxel ablumin plus gemcitabine regimen offered
more 0.154 QALYs and €7082.68 than gemcitabine alone
regimen. Incremental cost-utility ratio (€46,021.58) is lower
than the informal threshold value of €87,330 adopted by the
Italian Medicines Agency (INHS) during 2010–2013 for
reimbursing oncological drugs, which means that albumin-
bound paclitaxel plus gemcitabine can be considered a cost-
effective regimen for metastatic pancreatic cancer by the
Italian Medicines Agency.32 Moreover, a pharmacological
evaluation compared cost-effectiveness of gemcitabine, gem-
citabine plus 5-fluorouracil, gemcitabine plus capecitabine,
gemcitabine plus cisplatin, gemcitabine plus oxaliplatin,
gemcitabine plus erlotinib, gemcitabine plus nab-paclitaxel,
and FOLFIRINOX in the treatment of advanced pancreatic
cancer, the result demonstrated that FOLFIRINOX would be
the most optimal treatment for advanced pancreatic cancer as
the WTP threshold of $50,000 per QALY from a Canadian

Conclusion
Overall, the current study was the first study to compare
an adjuvant chemotherapy regimen in resected pancreatic
cancer from a cost-effectiveness perspective. The result
demonstrated that the gemcitabine monotherapy regimen is
more cost-effective when compared with the gemcitabine
plus capecitabine regimen for patients with postoperative
pancreatic cancer from the Chinese societal perspective.
Our analysis would contribute in aiding clinicians in mak-
ing optimal decision for the treatment of resected pancreatic
cancer patients.

Acknowledgment
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of Health Management and Policy, University of Michigan for
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Disclosure
The authors report no conflicts of interest in this work.

References