HGFK1 Association with a Better Prognosis and Reversal of Gefitinib Inhibition in NSCLCs

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Abstract

\textbf{Purpose:} Non small cell lung cancer (NSCLC) is the leading worldwide source of cancer-related deaths. Although some drugs targeting EGFR mutations have been developed, most advanced cases are still incurable. New targets for anticancer drugs are demanded. The kringle 1 domain of hepatocellular growth factor alpha chain (HGFK1) is a potent anti-angiogenesis factor. It has also emerged as a potential anticancer factor in hepatocellular carcinoma (HCC). The expression of HGFK1 protein in patients with NSCLC has not been reported to date. \textbf{Method:} Here, we assessed HGFK1 expression by Western blotting in 103 cases with advanced NSCLC to investigate the impact of HGFK1 on survival. \textbf{Results:} Results revealed 33 (30.1\%) patients were classified as high expressors, this being significantly associated with less remote metastasis (P = 0.002) but not with lymph node metastasis (P = 0.062). There was also a significant association between HGFK1 expression and tumor size (P = 0.025) as well as clinical stage (P = 0.012). Kaplan-Meier survival analysis showed that both overall survival (OS) and progression free survival (PFS) of patients with HGFK1 expression were longer than those of patients without HGFK1 expression (P = 0.004 and P = 0.001 respectively). HGFK1 reversed gefitinib inhibition in the resistant NSCLC cell line A431/GR but did not inhibit the proliferation of NSCLC cells A431 and A431/GR directly. Reversion of gefitinib inhibition in A431/GR cells by HGFK1 was related to decreased phosphorylation of ERK and STAT5. \textbf{Conclusions:} HGFK1 may be a useful prognostic factor of advanced NSCLC patients and a potential drug for gefitinib resistant patients.

Keywords: HGFK1 expression - non-small cell lung cancer - gefitinib resistance

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Introduction

Non small cell lung cancer (NSCLC), especially advanced NSCLC is the leading worldwide source of cancer-related deaths (Chorostowska-Wynimko and Szpechcinski, 2007). Some drugs targeting on EGFR mutations, such as erlotinib and gefitinib, have made a success in treating advanced NSCLC in past years (Gschwind et al., 2004; Hynes and Lane, 2005). Encouraging response to gefitinib is frequently observed in East Asian, female, adenocarcinoma histology, and non-smoking patients, and is closely associated with specific activating mutations in EGFR tyrosine kinase domain.

Since only 10-15\% of unselected NSCLC patients have specific activating mutations and 20-30\% of NSCLC patients have amplified wild-type EGFR (wtEGFR), more than 50\% of patients with NSCLC are not suitable for erlotinib and gefitinib treatment (Sharma et al., 2007; Ciardiello and Tortora, 2008). Furthermore, almost all patients had been sensitise to gefitinib treatment would become resistant to these drugs. New targets for anticancer drugs or new reagents for reversing inhibition by gefitinib on NSCLC cell are demanded (Pao et al., 2004; Bell et al., 2005; Cappuzzo et al., 2005).

HGFK1 is the kringle 1 domain of hepatocellular growth factor alpha chain (Xin et al., 2000). In vivo, HGFK1 inhibited tumor growth, decreased tumor microvessel density, and completely prevented intrahepatic, lung, and peritoneal metastasis. In vitro, HGFK1 exhibited both antiangiogenic and antitumor cell effects, inhibiting the proliferation of both murine microvascular endothelial cells (MEC) and tumor cells, and inducing apoptosis and $G(0)-G(1)$ phase arrest in these cells. The inhibition effects on MECs and tumor cell worked mainly through EGF/EGFR signaling, with more minor contributions from VEGF/VEGFR and bFGF/bFGFR signaling. It may thus be considered as a novel therapeutic strategy for the treatment of HCC (Nie et al., 2008; Shen et al., 2008a; Shen et al., 2008b). Certainly, substantial evidence from clinical data is needed to for HGFK1 to be a potential
target for anticancer drugs. The expression of HGFK1 and its function in NSCLC has not been reported to date. Here, we first assessed HGFK1 expression in 103 cases patients with advanced NSCLC to investigate the impact of HGFK1 on survival for the first time in our knowledge. Western blot was used to measure HGFK1 protein levels and classify tumors by HGFK1 expression in NSCLC patients. Then, we investigated the function of HGFK1 in NSCLC cell lines A431 and A431/GR. The possible pathway through which HGFK1 exerted its function was also investigated in this study.

Materials and Methods

Patients

A total of 103 patients with advanced NSCLC (III and IV stage) were studied. All samples were obtained by biopsy. Clinical and radiological examination discovered the suspicious patients with NSCLC, and then the definitive pathological diagnosis of NSCLC had made carried out by the CT-guided puncture or incisional biopsy.

The 7th AJCC Staging system was used to categorize patients: those who were stage III at initial diagnosis and those who presented with stage IV NSCLC. Among patients with Stage III NSCLC, metastatic recurrence was characterized as limited metastatic (defined above) or extensive metastatic disease. All patients were assessed with diagnostic CT or PET/CT imaging to identify metastatic lesions. Brain metastases were assessed with MRI. In some patients bone metastases were identified with bone scan and/or MRI.

Collection of 103 admitted patients of NSCLC from Feb. 2006 to Sept. 2010 in Cancer Center, the Medical School, Hospital of Qingdao University and Department of Oncology, The Affiliated Sixth People’s Hospital, Shanghai Jiaotong University. All patients were followed up after diagnosis. The basic demographics of this group and the pathological characteristics are shown in Table 1, respectively.

Western blot

For western blot, samples were homogenized in a solution of 10 mM HEPES, 10 mM KCl, 1.5 mM MgCl₂, 0.5 mM DTT, 0.5 mM PMSF, 10 μg/ml aprotinin, and 10 μg/ml leupeptin at pH 7.9. Protein extracts were then subjected to SDS-PAGE and transferred to a polyvinylidene difluoride membrane. The polyclonal antibody against HGFK1 was purchased from Zhongshen Biotechnology Inc. (Shanghai, China). The membrane was incubated with primary and secondary antibodies, respectively, for 1 hour at room temperature. Signals were developed by ECL Kit (Amersham Pharmacia Biotech Inc., Shanghai, China). The Image Quant Version 1 software (Mahata et al., 2011).

Cell lines and reagents

NSCLC cell lines A431 and acquired gefitinib resistant

### Table 1. Patient Demographics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. of Patients (N = 103)</th>
<th>Percentage (%)</th>
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<tbody>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;62</td>
<td>50</td>
<td>48.5</td>
</tr>
<tr>
<td>≥62</td>
<td>53</td>
<td>51.5</td>
</tr>
<tr>
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<td></td>
<td></td>
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<tr>
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<td>60.2</td>
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<tr>
<td>Female</td>
<td>41</td>
<td>39.8</td>
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<tr>
<td>Tumor size</td>
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<td></td>
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<tr>
<td>&lt;3 cm</td>
<td>39</td>
<td>37.9</td>
</tr>
<tr>
<td>≥3 cm</td>
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<td>62.1</td>
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<tr>
<td>Lymph node metastasis</td>
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<td></td>
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<tr>
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<td>35.9</td>
</tr>
<tr>
<td>Yes</td>
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<td>64.1</td>
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<td>Remote Metastasis</td>
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</tr>
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<td>57.3</td>
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<tr>
<td>Histological type</td>
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</tr>
<tr>
<td>Ad</td>
<td>50</td>
<td>48.6</td>
</tr>
<tr>
<td>SCC</td>
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<td>Ad+SCC</td>
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<td>4.9</td>
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<tr>
<td>Never</td>
<td>42</td>
<td>40.9</td>
</tr>
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</table>

Ad, adenocarcinoma; SCC, squamous cell carcinoma; Ad+SCC, Adenosquamous carcinoma

A431 (A431/GR) /GR were gifts from Dr. Carlos L. Arteaga (Vanderbilt-Ingram Cancer Center, Nashville, TN). A431/GR were cultured in the presence of 1 μM gefitinib as described previously (Engelman et al., 2007). Commercially available gefitinib and erlotinib were purchased from the pharmacy of affiliated Shanghai 6th People’s Hospital of Shanghai Jiao Tong University for the experiments described in this study. Epidermal growth factor (EGF), chrysin, and benzoflavone were purchased from Sigma-Aldrich (St. Louis, MO). Since anti-human HGFK1 antibodies were not commercially available, we designed synthetic peptide: RSY KGT VSI TK5 GIKC corresponding to the N-terminal amino acids of HGFK1 to produce rabbit polyclonal antisera against HGFK1. Anti-ERK, Anti-STAT5, Anti-pERK and Anti-pSTATs antibody from Santa Cruz Biotechnology, Inc. (Santa Cruz, CA) was used for Western blot. Signals were developed by ECL Kit (Amersham Pharmacia Biotech Inc., Buckinghamshire, UK).

Statistical analysis

The statistical significance of the correlation between expression of HGFK1 and several clinicopathological parameters was assessed by Fisher’s exact test, 2 test, or 2 test for trends as indicated. The probability of overall survival as a function of time was determined by the Kaplan-Meier method and the log-rank test. Multivariate survival analysis was performed using the Cox regression model. P values smaller than 0.05 were considered as significant. For the statistical evaluation, the SPSS software version 12.0 was used (SPSS, Inc., Chicago, IL).

Results

Investigation of HGFK1 expression in patients with NSCLC

The expression of HGFK1 in tumor samples of patients with NSCLC were investigated by Western blot (Figure 1). Tumor samples of 33 in 103 patients (30.1%) were
High HGFK1 expression is a prognostic factor for overall survival (OS) and progression-free survival (PFS) in univariate Kaplan-Meier analysis

In Kaplan-Meier survival analysis, high expression of HGFK1 was a significant prognostic indicator for overall survival (P = 0.004) as well as progression-free survival (P = 0.001) (Figure 2). In addition, the presence of metastases and histological grade were significant prognostic indicators for both overall survival and progression-free survival. Lymph node metastasis, clinical stage, and smoke status were also significant prognostic indicators for overall survival and progression-free survival.

HGFK1 reversed inhibition by gefitinib on A431/GR cell and did not enhance inhibition by gefitinib in A431 cell. Since HGFK1 was previously demonstrated to exert inhibition effect on liver cancer cell through EGFR signaling pathway, we wondered whether HGFK1 exerts inhibition effect on NSCLC cells. Results showed that no inhibition effect on A431 and A431/GR by treatment of HGFK1 alone was found.

We then treated A431 and A431/GR by gefitinib combined with HGFK1. Results showed that HGFK1 reversed inhibition by gefitinib on gefitinib resistance.
Investigating the role of anticancer therapies in the third- or fourth-line setting after EGFR TKI failure. An irreversible TKI targeting the EGFR, HER2, and vascular endothelial growth factor receptor was evaluated in the third- and fourth-line settings after EGFR TKI failure (Moyer et al., 1997). A small molecule Met inhibitor combined with an EGFR TKI has proven to be a reasonable strategy to overcome erlotinib-resistant T790M NSCLC (Li et al., 2008). Combining an insulin-like growth factor inhibitor with erlotinib to reverse resistance to erlotinib is also under investigation (Tang et al., 2008; Kosaka et al., 2011). However, most of these treatments are not clinically available.

Before this study, although its cellular function is still elusive, HGFK1 emerged to play a role as a tumor suppressor. No clinical evidence about the relationship between HGFK1 gene and tumor cell proliferation in the NSCLC is found up to date. Our data demonstrated that the high expression of HGFK1 was significantly associated with tumor size and remote metastasis but did not associate with lymph node metastasis. When HGFK1 expression is low, the tumor of NSCLC patients tends to grow faster and more easily metastasis to lymph node. There was also a significant association between HGFK1 expression and clinical stages observed.

We demonstrated a survival benefit for HGFK1 expression in patients without adenocarcinoma histology and this observation confirms the effect of adenocarcinoma histology for prognostic stratification of NSCLC patients. Although we do not yet know the mechanistic basis for this subgroup bias, we do acknowledge that such stratification might be relevant for future targeted therapy and/or early predictions of survival of patients with adenocarcinoma.

One interesting result of this study is that HGFK1 reverses the inhibition by gefitinib in gefitinib resistant NSCLC cell line A431/GR. Since TKI resistance becomes increasingly important in the treatment of NSCLC, our result provide promising insight for the use of HGFK1 in future investigations. Combined with the administration of HGFK1, gefitinib could be re-considered for those NSCLC patients who had already benefited from prior gefitinib treatment.

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References


