Phase II, Open-label Study of Brivanib as Second-line Therapy in Patients with Advanced Hepatocellular Carcinoma

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Running Title: Brivanib in Advanced HCC

Keywords: brivanib, fibroblast growth factor, hepatocellular carcinoma, modified RECIST, vascular endothelial growth factor

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- American Society for Clinical Oncology 2009 meeting
- Chinese Society for Clinical Oncology 2009 and 2010 meetings
- Korean Association for the Study of Liver 2010 meeting
- International Liver Cancer Association 2009 and 2010 meetings

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Translational Relevance

The only systemic agent that has been shown to improve survival in patients with advanced hepatocellular carcinoma (HCC) is sorafenib, an oral multikinase inhibitor that targets vascular endothelial growth factor (VEGF) signalling. However, many patients do not receive benefit with sorafenib, and those who do eventually progress. Recent clinical data suggest that upregulation of alternate proangiogenic signalling pathways, such as the fibroblast growth factor (FGF) signalling pathway, may play a role in the development of resistance with anti-VEGF therapies. These findings provide the rationale for the current phase II study evaluating brivanib, an oral selective dual inhibitor of FGF and VEGF signalling. This study demonstrates the antitumor activity and tolerability of brivanib in patients with advanced HCC who had progressive disease while taking 1 prior antiangiogenic therapy (primarily sorafenib), and supports the ongoing phase III program in HCC. The current manuscript also incorporates an analysis using the newly proposed mRECIST.
Abstract

**Purpose:** Brivanib, a selective dual inhibitor of fibroblast growth factor and vascular endothelial growth factor signalling, has recently been shown to have activity as first-line treatment for patients with advanced hepatocellular carcinoma (HCC). This phase II open-label study assessed brivanib as second-line therapy in patients with advanced HCC who had failed prior antiangiogenic treatment.

**Experimental design:** Brivanib was administered orally at a dose of 800 mg once daily. The primary objectives were tumor response rate, time to response, duration of response, progression-free survival, overall survival (OS), disease control rate, time to progression (TTP), and safety and tolerability.

**Results:** Forty-six patients were treated. Best responses to treatment with brivanib (N = 46 patients) using modified World Health Organization criteria were partial responses for 2 patients (4.3%), stable disease for 19 patients (41.3%), and progressive disease for 19 patients (41.3%). The tumor response rate was 4.3%; the disease control rate was 45.7%. Median OS was 9.79 months. Median TTP as assessed by study investigators following second-line treatment with brivanib was 2.7 months. The most common adverse events were fatigue, decreased appetite, nausea, diarrhea, and hypertension.

**Conclusion:** Brivanib had a manageable safety profile and is one of the first agents to demonstrate promising antitumor activity in advanced HCC patients treated with prior sorafenib.
**Key words:** brivanib, fibroblast growth factor, hepatocellular carcinoma, modified RECIST, vascular endothelial growth factor
Introduction

Hepatocellular carcinoma (HCC) is the fifth most common malignancy worldwide (1) and the third leading cause of cancer-related death (2). Angiogenesis plays a key role in growth and metastasis of many tumors, including HCC (3), and is generally mediated by several growth factors, including the fibroblast growth factor (FGF) and vascular endothelial growth factor (VEGF) families (4). Agents that target the VEGF axis provide a survival benefit in patients with advanced-stage HCC (5, 6). Nevertheless, current VEGF-targeted agents fail to produce enduring clinical responses in most patients as a result of de novo or acquired resistance (7, 8). With regard to HCC, the only systemic agent that has been shown to improve survival is sorafenib, an oral multikinase inhibitor (5, 6). Beyond sorafenib, several studies are evaluating novel combinations (9), and although benefits have been observed with sorafenib, other single agents (eg, sunitinib) have not demonstrated efficacy in HCC (10).

To overcome these challenges, the FGF pathway is being pursued as a therapeutic target in HCC. FGF belongs to a family of heparin-binding, multifunctional proteins that bind to one of 4 isoforms of FGF receptors (FGFR 1 to 4) (11). FGF signalling regulates fundamental cellular developmental processes, (12) and aberrant FGF signalling is associated with tumorigenesis (8, 11–13). In addition, FGF-2 has potent effects on vascular endothelial cell proliferation (14), and levels are elevated in tumors and/or serum in patients with a variety of cancers, including HCC (15–18). Recent clinical data suggest that upregulation of alternate proangiogenic signaling pathways, such as the
FGF signalling pathway, may play a role in the development of resistance with anti-VEGF therapies (19–22).

Brivanib, an oral, selective dual inhibitor of FGFR and VEGF receptor (VEGFR) tyrosine kinases, has demonstrated antitumor activity in preclinical models of various cancers, including HCC (23–27). Brivanib has a half-life of 12 hours and is administered once daily at a dose of 800 mg. In addition, no differences in pharmacokinetics between Asian versus non-Asian subjects have been reported (28). A recent phase II study of brivanib as first-line treatment in 55 patients with advanced HCC reported a response rate of 7.3% and a disease control rate (DCR) of 51% (29). Median progression-free survival (PFS) and overall survival (OS) were 2.7 and 10 months, respectively. Brivanib was generally well tolerated; the most common adverse events (AEs) included fatigue, hypertension, and diarrhea.

Here we present the results from an assessment of brivanib as second-line therapy in patients with advanced HCC. Importantly, this is the first completed study of a targeted agent in patients with advanced HCC who had progressive disease while taking 1 prior antiangiogenic therapy (primarily sorafenib).

Methods

Study design

This was a multicenter, open-label, phase II, single-agent study of once-daily brivanib alaninate 800 mg in patients with unresectable, locally advanced, and/or metastatic HCC who had received 1 prior antiangiogenic therapy
regimen. It was initiated following approval of sorafenib for the treatment of HCC, and was carried out in accordance with the Declaration of Helsinki and International Conference on Harmonization-Good Clinical Practice. The study protocol and any amendments were approved by the independent ethics committee of each center and by the authorities in each relevant country. Informed consent was obtained from each patient.

Sample size determination

The sample size was derived from an amended protocol at the time of sorafenib approval without another formal power calculation, and was not determined by a statistical hypothesis. After sorafenib’s approval, this study became a signal-finding phase II study for this newly defined population. This was originally a randomized study of brivanib versus doxorubicin in newly diagnosed HCC patients. At the time the protocol was initiated, no agent was proven to extend survival in HCC, and doxorubicin was used as a comparator arm. Based on positive phase III results with sorafenib (5), the study protocol was amended to discontinue the doxorubicin arm and to include patients who had progressed following a maximum of 1 prior treatment (the cohort included in this study). The study protocol was amended again later to include a cohort with second-line brivanib 400 mg twice daily. The master protocol included 3 patient cohorts: first-line brivanib 800 mg once daily, second-line brivanib 800 mg once daily, and second-line brivanib 400 mg twice daily. Results with the first-line brivanib cohort in this study are reported elsewhere (29).
Inclusion and exclusion criteria

To be eligible, patients had to meet the following inclusion criteria: (1) measurable, unresectable, locally advanced, and/or metastatic HCC that was either biopsy proven or had clinical evidence of HCC (fulfilling standard imaging criteria for HCC and having an α-fetoprotein [AFP] level ≥ 400 mg/L) with positive serology for hepatitis B or C virus; (2) had progressed on one prior antiangiogenic therapy or discontinued treatment due to treatment-related toxicity and subsequently progressed prior to study entry; (3) had a Cancer of the Liver Italian Program (CLIP) score ≤ 3; (4) had an Eastern Cooperative Oncology Group performance status of 0 to 2; and (5) had adequate hepatic function (total bilirubin ≤ 2.5 mg/dL, aspartate aminotransferase/alanine aminotransferase ≤ 5 times the upper limit of normal, serum albumin > 2.8 g/dL, prothrombin time/international normalized ratio ≤ 1.8, unless on therapeutic anticoagulation) and renal function.

Key exclusion criteria included: (1) CLIP score ≥ 3; (2) active bacterial infections, HIV/AIDS, or other diseases that would preclude study participation; (3) gastrointestinal tract disease or prior surgery; (4) pregnant or breast-feeding women; (5) primary malignancy in past 5 years; (6) mental incapacitation or psychiatric illness; and (7) uncontrolled or significant cardiovascular disease.

History of portal hypertension was not collected in the case report form; however, study entry restrictions included: clinically significant ascites refractory to diuretic therapy; presence of portal-systemic encephalopathy.
(evidenced by confusion, asterixis, significant sleep disturbance, or hypothermia less than 36º Celsius); evidence of portal hypertension with bleeding esophageal or gastric varices within the past 2 months; and prior variceal bleed permitted if the patient had undergone banding and there had been no evidence of bleeding for 2 months.

**Study endpoints**

The primary endpoints of this trial were tumor response rate, time to response, duration of response, PFS, OS, DCR, time to progression (TTP), and safety and tolerability. The tumor response rate was the proportion of patients with a complete response (CR) or partial response (PR), and time to response was the time from the day of first dose until the first day criteria were met for CR or PR, whichever occurred first. The duration of response was the time from the first day all criteria were met for CR or PR, whichever occurred first, to the date progressive disease was first documented, or date of death. OS was the time from the day of first dose to the date of death. DCR was the proportion of treated subjects whose best response was PR, CR, or stable disease (SD) lasting \( \geq 42 \) days.

**Treatment**

Patients were required to have progressive disease while taking 1 prior antiangiogenic therapy. In the assessment of progression on prior antiangiogenic therapy, the case record form collected progression data as retrospectively assessed by the investigator based on medical practice, and did not define or seek to confirm that these were indeed progressions. A 4-
week washout period prior to receiving brivanib was required. Brivanib was administered orally on a continuous once-daily schedule of 800 mg until disease progression or unacceptable toxicity. Doses were reduced or delayed according to protocol-specified criteria or, for lower grade toxicities, if the investigator deemed dose reduction or delay was required in the interest of the patient’s safety.

**Efficacy assessment**

Tumor response was assessed every 6 weeks using the modified World Health Organization (mWHO) tumor response criteria via computed tomography/magnetic resonance imaging. Tumor assessment was performed by study investigators and by an Independent Response Review Committee (IRRC).

**Post hoc exploratory analysis of efficacy with modified Response Evaluation Criteria in Solid Tumors**

This study was designed in April 2006 prior to the recent American Association for the Study of Liver Diseases-Journal of the National Cancer Institute (AASLD-JNCI) guidelines for HCC, which recommend alternative assessment of tumor responses, taking into account the viability of hepatic tumors using the new modified Response Evaluation Criteria in Solid Tumors (mRECIST) for HCC (30, 31). Using mRECIST for HCC, scans were retrospectively reassessed by an independent radiologist who was blinded to previous imaging and outcome results, and was not involved in the initial
reads. All atypical intrahepatic and all extrahepatic lesions were assessed using conventional RECIST.

**Biomarker assessment**

In this study, serum AFP levels were collected at the same time points as disease assessments.

Collagen IV is a component of vascular basement membranes that appears to be elevated in the serum of HCC patients compared with those with chronic hepatitis or cirrhosis and has previously been identified as a potential pharmacodynamic biomarker of brivanib treatment (32). Whole blood samples for the measurement of plasma levels of collagen IV were drawn pre-dose on the day of the first brivanib dose (day 1), at week 3 (day 22), week 6 (day 43), and end of treatment. Plasma collagen IV was measured using an enzyme-linked immunosorbent assay kit (Biotrin International, Ltd; Dublin, Ireland).

**Safety assessment**

Safety was assessed via AEs, vital signs, physical examinations, and clinical laboratory tests, and graded according to National Cancer Institute Common Terminology Criteria, Version 3.0. Physical examinations were performed weekly during the first month and every 3 weeks thereafter, or more frequently as clinically indicated. Physical examinations included assessment of mental status and neurologic changes.
Results

Patients

Forty-six patients received second-line systemic therapy with brivanib 800 mg once daily (Supplementary Fig. 1). Baseline characteristics are presented in Table 1. Of these patients, 72% were male, 67% were Asian, and 33% were non-Asian; 43 (93.5%) had progressed on sorafenib and 3 (6.5%) had progressed on thalidomide. Vascular invasion (portal vein invasion and/or portal vein thrombosis) was present at baseline in 7 patients (15.2%). Best responses to prior antiangiogenic therapy were 1 PR (2.2%), 15 SD (32.6%), 29 progressive disease (63.0%), and 1 unable to determine (2.2%). Median duration of prior antiangiogenic therapy was 3.14 months (range 0.26–11.47). Reasons for stopping prior antiangiogenic therapy were disease progression in 43 patients (93.5%) and toxicity in 3 (6.5%). Median TTP for 44 patients who had radiographic progression under prior antiangiogenic therapy was 2.97 months based on 44 events.

Efficacy results

Response to treatment with brivanib is summarized in Table 2. Best responses to treatment with brivanib using mWHO criteria per IRRC were PR for 2 patients (4.3%), SD for 19 patients (41.3%), progressive disease for 19 patients (41.3%), and unable to determine due to availability of only baseline scans in 6 patients (13.0%); the tumor response rate was 4.3% and the DCR was 45.7%. Best responses using mWHO criteria, per investigator, were PR in 2 patients (4.3%), SD in 20 patients (43.5%), progressive disease in 15 patients (32.6%), and unable to determine in 9 patients (19.6%) due to
discontinuation prior to disease assessment; the tumor response rate was
4.3% and the DCR was 47.8%. Median TTP per mWHO criteria assessed by
IRRC was 1.77 months (95% confidence interval [CI], 1.38–4.01) (Fig. 1A).
Median OS was 9.79 months (95% CI, 5.52–13.17) (Fig. 1B). Median PFS
was 2.00 months (95% CI, 1.41–3.91) assessed by IRRC and 2.73 months
(95% CI, 1.45–4.04) assessed by study investigators.

Results of post hoc exploratory analysis of efficacy using mRECIST
Best responses using HCC mRECIST per retrospective review by an
independent radiologist were PR in 5 patients (10.9%), SD in 28 patients
(60.9%), progressive disease in 7 patients (15.2%), and unable to determine
in 6 patients (13.0%) due to the fact that only baseline images were available
for review using mRECIST; the tumor response rate was 10.9% and the DCR
was 71.7%. Median TTP per mRECIST was 6.9 months (95% CI, 3.9–not
reached) (Fig. 1A). Responses to brivanib were higher with mRECIST versus
mWHO criteria.

Biomarker results
AFP responses (best on-study decrease from baseline) of > 50% and ≤ 50%
were reported in 23 patients (50.8%) and 21 patients (45.7%), respectively
(Table 2). AFP responses were not reported for 2 patients (4.3%; Table 2).
For patients with evaluable response as well as AFP changes (ie, baseline
AFP greater than the upper limit of normal and at least one on-study AFP
measure), percent AFP change from baseline and radiographic response by
mWHO criteria and mRECIST are presented in Figures 2A and 2B,
respectively. All patients who had a PR, regardless of assessment tool, had a > 50% decrease from their baseline AFP value. In addition, a number of patients with SD had a > 50% decrease from their baseline AFP value. Figure 2C shows survival for the same population of patients, comparing those who had a > 50% decrease from baseline in AFP value with those who did not. Median OS was 10.8 months for patients with a > 50% decrease from baseline in AFP vs 7.3 months for those without such an AFP response, with a hazard ratio of 0.67 (95% CI, 0.31–1.45).

Collagen IV levels were reduced at week 3 of brivanib treatment (day 21) and levels were maintained until week 6 regardless of response to brivanib (Fig. 2D). At baseline, median (quartile [q]1, q3) collagen IV levels were 293.80 ng/mL (195.0–459.8; n = 39). At week 3, the median (q1, q3) change from baseline in collagen IV levels was -69.10 ng/mL (-143.4–32.8 ng/mL; n = 32). At week 6, the median (q1, q3) change from baseline in collagen IV levels was -71.60 ng/mL (-150.0–31.1 ng/mL; n = 29).

**Safety**

On-study AEs were reported for all patients; 4 patients (8.7%) had grade 1 AEs, 18 (39.1%) had grade 2 AEs, 20 (43.5%) had grade 3 AEs, 2 (4.3%) had grade 4 AEs, and 4 (8.6%) had grade 5 AEs. The most common AEs are summarized in Table 3. The most frequently reported grade 3/4 AEs were hypertension (8.7%), hyponatremia (8.7%), decreased platelet count (6.5%), and diarrhea (6.5%). The 4 patients with grade 5 AEs had renal failure, cholecystitis, and disease progression. Hand-foot syndrome was rare, with
only 6 of 46 patients (13%) experiencing this AE (all grade 1/2). Weight loss was reported in 5 patients (10.9%) and was generally mild (grade 1 in 3 patients and grade 2 in 2 patients). Encephalopathy was reported in 4 patients (8.7%), and was grade 2 in 2 patients and grade 3 in 2 patients. No grade 3/4 dermatologic AEs were observed. On-study drug-related AEs were reported for 43 (93.5%) patients: grade 1 in 10.9%, grade 2 in 41.3%, and grade 3 in 41.3%. Serious AEs were reported for 17 patients (37.0%). Thirteen patients (28.3%) had grade 3/4 serious AEs, and 2 patients (4.3%) had grade 5 serious AEs, both of which were considered unrelated to brivanib. Twelve patients (26.1%) discontinued the study due to AEs (7 [15.2%] were considered related to brivanib). AEs leading to discontinuation in at least 2 patients were vomiting (2 patients; grade 3) and hypertension (3 patients; grade 2/3). Bleeding events were uncommon and included rectal hemorrhage (1 patient, grade 1), bloody discharge (1 patient, grade 1), epistaxis (3 patients, grade 1), and tumor hemorrhage (1 patient, grade 2). Three patients died within 30 days of the last dose of brivanib; the cause of death was underlying disease progression in 2 patients and a combination of acute renal failure and cholecystitis in the third. In addition, 28 (66.7%) patients had elevated thyroid-stimulating hormone levels. Grade 4 laboratory abnormalities included 1 report in each of the following: thrombocytopenia, neutropenia, and renal dysfunction with hyponatremia and elevated creatinine.

Discussion

The approval of sorafenib was a significant step forward in the treatment of advanced HCC. However, still many patients do not receive benefit with
sorafenib, and those who do eventually progress. This study is one of the first to report on a novel therapeutic agent for advanced HCC in the post-sorafenib era.

In this single-arm, phase II study, brivanib treatment appeared to provide additional clinical benefit to patients with advanced HCC who had progressive disease while taking 1 prior antiangiogenic therapy (primarily sorafenib). This patient population currently has no proven therapeutic options. Overall, at least 40% of patients appear to have experienced a clinical benefit that exceeded that reported with their prior antiangiogenic agent. While encouraging, these data will require prospective confirmation.

This study is also one of the first to report an exploratory analysis using mRECIST, the newly proposed response criteria by the AASLD-JNCI (30, 31). It has been proposed that changes in the unique imaging characteristics of HCC must be considered when assessing response of novel therapeutics in HCC clinical trials. Specifically, the hypervascular nature of HCC and its characteristic enhancement on contrast imaging must be taken into consideration when assessing the “longest tumor diameter” as is commonly done with RECIST (33). It is proposed that changes in the hypervascular component are considered. Results from a recent retrospective analysis of patients treated for advanced HCC suggest that the use of mRECIST may be a better way of assessing treatment efficacy with sorafenib (34). In the current study, the responses to brivanib were higher based on mRECIST compared with mWHO criteria. Median TTP was 6.9 months per mRECIST versus 1.77
months per mWHO criteria assessed by IRRC. Further validation of these new assessment criteria is ongoing in the phase III randomized brivanib trials and will better define if mRECIST is a better predictor for OS and benefit than conventional assessment criteria (RECIST).

As expected, the activity of brivanib in a pretreated population is less than that in a treatment-naïve population (29). For comparison using mWHO criteria, in the first-line brivanib study, 1 patient achieved a CR, 3 patients achieved a PR, and 24 had SD, while in the present study only 2 patients had a PR and 19 achieved SD. Median PFS (assessed by IRRC) and OS were 2.7 and 10 months, respectively, in the first-line setting (29), and 2.00 and 9.79 months in the present study. Similarly, median TTP (assessed by IRRC) was 2.8 months in the first-line setting (29) and 1.77 months in the present study. The apparent disconnection between OS and TTP may be a reflection of the initial interpretation of response based on mWHO; in the present study, DCR based on mRECIST was greater than that based on mWHO.

We performed exploratory biomarker analyses as part of this phase II study. While the utility of AFP values and the optimal method to interpret AFP changes in the treatment of patients with advanced HCC remain controversial, we determined that all patients with a radiographic response by either mWHO criteria or mRECIST had a > 50% decrease from baseline in AFP, as did a number of patients with SD. Additionally, there was a trend towards better survival in patients with a > 50% decrease from baseline in AFP versus those without such an AFP response. In addition, data from this study recapitulate
the preclinical observation that brivanib modulates serum collagen IV levels. However, it is unclear as to whether this effect is FGF mediated. The utility of both AFP and collagen IV as predictive markers of response will require further study.

Safety results from the present analysis of brivanib as second-line treatment and those from the analysis of brivanib as first-line treatment in patients with HCC (29) indicate that this agent has a manageable safety profile, with the most common AEs being fatigue, decreased appetite, nausea, diarrhea, and hypertension. Although the current results are from an open-label, single-arm study, they compare favorably with sorafenib outcomes in 2 large randomized, placebo-controlled phase III trials (5, 6). Specifically, brivanib has a very low incidence of hand-foot skin reaction, which is often a limiting toxicity with sorafenib. Clinically significant hypertension is more common with brivanib than with sorafenib (5, 6), and this may be a reflection of a more potent antiangiogenic effect. There were 3 deaths recorded within 30 days of completing study therapy, but none of those deaths were felt to be drug related in this study with advanced, treatment refractory HCC.

In conclusion, this single-arm study demonstrates the activity and safety of brivanib in patients with advanced HCC after progression with sorafenib. These phase II results, together with the scientific rationale that dual FGFR and VEGFR inhibition may overcome VEGF therapy resistance, supports the ongoing phase III study of brivanib versus placebo in patients intolerant of, or progressing on, sorafenib (NCT00825955). This will further inform the
tolerability and efficacy of brivanib in this population with unmet need, and will provide prospective, randomized data to fully assess the utility of mRECIST in HCC trials.

Acknowledgments

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Preclinical pharmacokinetics and in vitro metabolism of brivanib (BMS-


Table 1. Baseline demographic and clinical characteristics of patients treated

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N = 46</th>
</tr>
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<tbody>
<tr>
<td>Median age, y (range)</td>
<td>55 (21–81)</td>
</tr>
<tr>
<td>Gender, male/female, %</td>
<td>72/28</td>
</tr>
<tr>
<td>Race, Asian/non-Asian, %</td>
<td>67/33</td>
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<tr>
<td>Positive status for HBV/HCV, %</td>
<td>65/17</td>
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<tr>
<td>ECOG performance status 0/1/2, %</td>
<td>26/72/2</td>
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<tr>
<td>Extrahepatic spread(^a), %</td>
<td>78</td>
</tr>
<tr>
<td>Vascular invasion, %</td>
<td>15</td>
</tr>
<tr>
<td>Child-Pugh status A/B, %</td>
<td>91/9</td>
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<tr>
<td>BCLC stage B/C, %</td>
<td>4/96</td>
</tr>
<tr>
<td>CLIP stage 0/1/2/3, %</td>
<td>9/30/39/22</td>
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<tr>
<td>AFP &gt; ULN, %</td>
<td>83</td>
</tr>
<tr>
<td>Prior local therapy (TACE, RFA, etc)(^b), %</td>
<td>83</td>
</tr>
<tr>
<td>Sorafenib/thalidomide, %</td>
<td>94/6</td>
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<tr>
<td>Median duration, months (range)</td>
<td>3.14 (0.3–11.5)</td>
</tr>
</tbody>
</table>

BCLC, Barcelona Clinic Liver Cancer staging system; ECOG, Eastern Cooperative Oncology Group; HBV, hepatitis B virus; HCV, hepatitis C virus; RFA, radiofrequency ablation; TACE, transarterial chemoembolization; ULN, upper limit of normal.

\(^a\)Indirectly calculated from IRRC tumor reports.

\(^b\)No patients had prior surgical resection, radiotherapy, and transplant.
Table 2. Summary of outcomes for second-line brivanib treatment in patients with HCC

<table>
<thead>
<tr>
<th>Measure</th>
<th>Results</th>
</tr>
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<tbody>
<tr>
<td>Best response using mWHO criteria, per IRRC</td>
<td>• PR: 2 (4.3%)</td>
</tr>
<tr>
<td></td>
<td>• SD: 19 (41.3%)</td>
</tr>
<tr>
<td></td>
<td>• Progressive disease: 19 (41.3%)</td>
</tr>
<tr>
<td></td>
<td>• Unable to determine: 6 (13.0%)</td>
</tr>
<tr>
<td></td>
<td>• Tumor response rate: 2 (4.3%)</td>
</tr>
<tr>
<td></td>
<td>• DCR: 21 (45.7%)</td>
</tr>
<tr>
<td>Best response using mWHO criteria, per investigator</td>
<td>• PR: 2 (4.3%)</td>
</tr>
<tr>
<td></td>
<td>• SD: 20 (43.5%)</td>
</tr>
<tr>
<td></td>
<td>• Progressive disease: 15 (32.6%)</td>
</tr>
<tr>
<td></td>
<td>• Unable to determine: 9 (19.6%)</td>
</tr>
<tr>
<td></td>
<td>• Tumor response rate: 2 (4.3%)</td>
</tr>
<tr>
<td></td>
<td>• DCR: 22 (47.8%)</td>
</tr>
<tr>
<td>Best response using HCC mRECIST criteria, per independent radiologist</td>
<td>• PR: 5 (10.9%)</td>
</tr>
<tr>
<td></td>
<td>• SD: 28 (60.9%)</td>
</tr>
<tr>
<td></td>
<td>• Progressive disease: 7 (15.2%)</td>
</tr>
<tr>
<td></td>
<td>• Unable to determine: 6 (13.0%)</td>
</tr>
<tr>
<td></td>
<td>• Tumor response rate: 5 (10.9%)</td>
</tr>
<tr>
<td></td>
<td>• DCR: 33 (71.7%)</td>
</tr>
<tr>
<td>Median OS, months</td>
<td>9.79 (95% CI, 5.52–13.17)</td>
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<tr>
<td>Median PFS, months</td>
<td></td>
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<tr>
<td>Per IRRC</td>
<td>2.00 (95% CI, 1.41–3.91)</td>
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<tr>
<td>Per Investigator</td>
<td>2.73 (95% CI, 1.45–4.04)</td>
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<tr>
<td>AFP response</td>
<td>• &gt; 50%: 23 (50.8%)</td>
</tr>
<tr>
<td></td>
<td>• ≤ 50%: 21 (45.7%)</td>
</tr>
<tr>
<td></td>
<td>• Not reported: 2 (4.3%)</td>
</tr>
</tbody>
</table>
Table 3. Adverse events (all grades occurring in > 10% of patients)

<table>
<thead>
<tr>
<th>Adverse Event</th>
<th>Grade 1/2</th>
<th>Grade 3/4</th>
<th>N = 46 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue</td>
<td>25 (54.4)</td>
<td>2 (4.3)</td>
<td>27 (58.7)</td>
</tr>
<tr>
<td>Decreased appetite</td>
<td>25 (54.3)</td>
<td>0</td>
<td>25 (54.3)</td>
</tr>
<tr>
<td>Nausea</td>
<td>18 (39.2)</td>
<td>2 (4.3)</td>
<td>20 (43.5)</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>16 (34.7)</td>
<td>3 (6.5)</td>
<td>19 (41.3)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>15 (32.6)</td>
<td>4 (8.7)</td>
<td>19 (41.3)</td>
</tr>
<tr>
<td>Vomiting</td>
<td>14 (30.4)</td>
<td>2 (4.3)</td>
<td>16 (34.8)</td>
</tr>
<tr>
<td>Headache</td>
<td>9 (19.5)</td>
<td>2 (4.3)</td>
<td>11 (23.9)</td>
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<tr>
<td>Stomatitis</td>
<td>11 (23.9)</td>
<td>0</td>
<td>11 (23.9)</td>
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<tr>
<td>Constipation</td>
<td>10 (21.7)</td>
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<td>10 (21.7)</td>
</tr>
<tr>
<td>Hypothyroidism</td>
<td>7 (15.2)</td>
<td>1 (2.2)</td>
<td>8 (17.4)</td>
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<tr>
<td>Musculoskeletal pain</td>
<td>7 (15.2)</td>
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<tr>
<td>Cough</td>
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<td>Dysphonia</td>
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<td>Abdominal pain</td>
<td>4 (8.7)</td>
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<tr>
<td>Abdominal pain upper</td>
<td>5 (10.8)</td>
<td>1 (2.2)</td>
<td>6 (13.0)</td>
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<td>Dyspepsia</td>
<td>6 (13.0)</td>
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<td>Back pain</td>
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<td>Dizziness</td>
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<td>Palmar-plantar erythrodysesthesia syndrome</td>
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<td>Rash</td>
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<td>Hyponatremia</td>
<td>1 (2.2)</td>
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<tr>
<td>Platelet count decreased</td>
<td>2 (4.3)</td>
<td>3 (6.5)</td>
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<td>Weight decreased</td>
<td>5 (10.8)</td>
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<td>5 (10.9)</td>
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**Figure Legends**

**Figure 1.** A, Kaplan-Meier curves for time to progression (TTP) according to mWHO criteria (IRRC assessment) and mRECIST; B, Kaplan-Meier curve for overall survival (OS). NR, not reached.

**Figure 2.** A, Waterfall plot of best tumor response using modified World Health Organization (mWHO) criteria and best on-study decrease from baseline in α-fetoprotein (AFP) in patients with elevated baseline AFP (greater than the upper limit of normal); B, Waterfall plot of best tumor response using modified Response Evaluation Criteria in Solid Tumors (mRECIST) for hepatocellular carcinoma and best on-study decrease from baseline in AFP in patients with elevated baseline AFP (greater than the upper limit of normal); C, Overall survival (OS) by AFP response (> 50% decrease from baseline in AFP) in patients with elevated baseline AFP (greater than upper limit of normal); D, Circulating collagen IV levels at baseline and on study. IQR, interquartile range.
Figure 1A

Patients at risk
mWHO 46 16 10 5 1 0 0
mRECIST 46 21 15 8 4 1 0

Median TTP (95% CI)
mWHO 1.77 mo (1.38–4.01)
mRECIST 6.9 mo (3.9–NR)
Figure 1B

Median OS (95% CI)
9.79 mo (5.52–13.17)
Best Tumor Response Using mWHO Criteria

Number of treated patients = 46
Number of patients with baseline AFP greater than upper limit of normal and at least one on-study AFP measurement = 36
Figure 2B

Best Tumor Response Using mRECIST

Number of treated patients = 46
Number of patients with baseline AFP greater than upper limit of normal and at least one on-study AFP measurement = 36

Maximum reduction from baseline in AFP value (%)

-70
-60
-50
-40
-30
-20
-10
0
10
20
30
-80
-90
-100

Individual patient

PR (per IRRC)
SD (per IRRC)
Patients at risk

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Proportion alive

- **AFP response**
  - Median OS (95% CI): 10.8 mo (5.5–15.1)
  - Hazard ratio (95% CI): 0.67 (0.31–1.45)

- **AFP non-response**
  - Median OS (95% CI): 7.3 mo (3.9–14.3)

Number of treated patients = 46

Number of patients with treated AFP level then greater than upper limit of normal and at least one on-study AFP measurement = 36

AFP response defined as >50% decrease in AFP levels
Figure 2D

Box plots showing the distribution of Collagen IV (ng/mL) levels at different time points:

- Week 3: n = 38
- Week 6: n = 29

Key:
- *: Maximum observation
- Upper fence (not drawn): 1.5 (IQR) above 75th percentile
- Maximum observation below upper fence
- IQR: 75th percentile
- Mean
- Median
- 25th percentile
- Lower fence (not drawn): 1.5 (IQR) below 25th percentile
# Clinical Cancer Research

## Phase II, Open-label Study of Brivanib as Second-line Therapy in Patients with Advanced Hepatocellular Carcinoma

Richard S. Finn, Yoon-Koo Kang, Mary Mulcahy, et al.

*Clin Cancer Res* Published OnlineFirst January 11, 2012.

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| Supplementary Material | Access the most recent supplemental material at: [http://clincancerres.aacrjournals.org/content/suppl/2012/01/11/1078-0432.CCR-11-1991.DC1](http://clincancerres.aacrjournals.org/content/suppl/2012/01/11/1078-0432.CCR-11-1991.DC1)  
[http://clincancerres.aacrjournals.org/content/suppl/2012/03/28/1078-0432.CCR-11-1991.DC2](http://clincancerres.aacrjournals.org/content/suppl/2012/03/28/1078-0432.CCR-11-1991.DC2) |
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