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To the editor:

Long-term follow-up of patients with CLL treated with the selective Bruton's tyrosine kinase inhibitor ONO/GS-4059

Harriet S. Walter,[1] Sandrine Jayne,[1] Simon A. Rule,[2] Guillaume Cartron,[3] Franck Morschhauser,[4,5] Salvador Macip,[1] Lionel Karlin,[6] Ceri Jones,[7] Charles Herbaux,[4,5] Philippe Quittet,[3] Nimish Shah,[2] Claire V. Hutchinson,[1,2] Christopher Fegan,[7] Yingsi Yang,[8] Siddhartha Mitra,[8] Gilles Salles,[6] and Martin J. S. Dyer[1]

[1]Ernest and Helen Scott Haematological Research Institute, University of Leicester, Leicester, United Kingdom; [2]Department of Clinical Haematology, Plymouth University Peninsula Schools of Medicine and Dentistry, Plymouth, United Kingdom; [3]Department of Clinical Hematology and Unité Mixte de Recherche–Centre National de la Recherche Scientifique 5235, Centre Hospitalier Régional Universitaire, Montpellier, France; [4]EA 7365 Groupe de Recherche sur les Formes Injectables et les Technologies Associées, University of Lille, Lille, France; [5]Department of Hematology, Centre Hospitalier Régional Universitaire, Lille, France; [6]Hospices Civils de Lyon, Centre Hospitalier Lyon Sud, Service d'Hématologie, Pierre-Bénite, Université Claude Bernard Lyon 1, Lyon, France; [7]Cardiff Chronic Lymphocytic Leukemia Research Group, School of Medicine, Cardiff University, Cardiff, United Kingdom; and [8]Gilead Sciences, Inc, Foster City, CA

The inhibitor of Bruton's tyrosine kinase (BTK) ibrutinib has transformed the treatment of chronic lymphocytic leukemia (CLL); many patients with previously untreatable disease may now enter durable remissions.[1,2] Nevertheless, the kinome of ibrutinib is broad, resulting in toxicities including bleeding, arthralgia, diarrhea, hypertension, and atrial fibrillation.[3-6] Up to 20% of patients discontinue ibrutinib due to toxicity.[7-9] More selective BTK inhibitors (BTKis) include ONO/GS-4059, acalabrutinib, and BGB-3111. Preliminary data indicate that these drugs have comparable activity to ibrutinib, but with reduced toxicities.[10-12] However, long-term follow-up and response data have not yet been reported. We provide an updated, 3-year follow-up of treatment efficacy, safety, and laboratory correlates, including baseline mutational profiling of CLL patients in the phase 1 ONO/GS-4059 extension study.

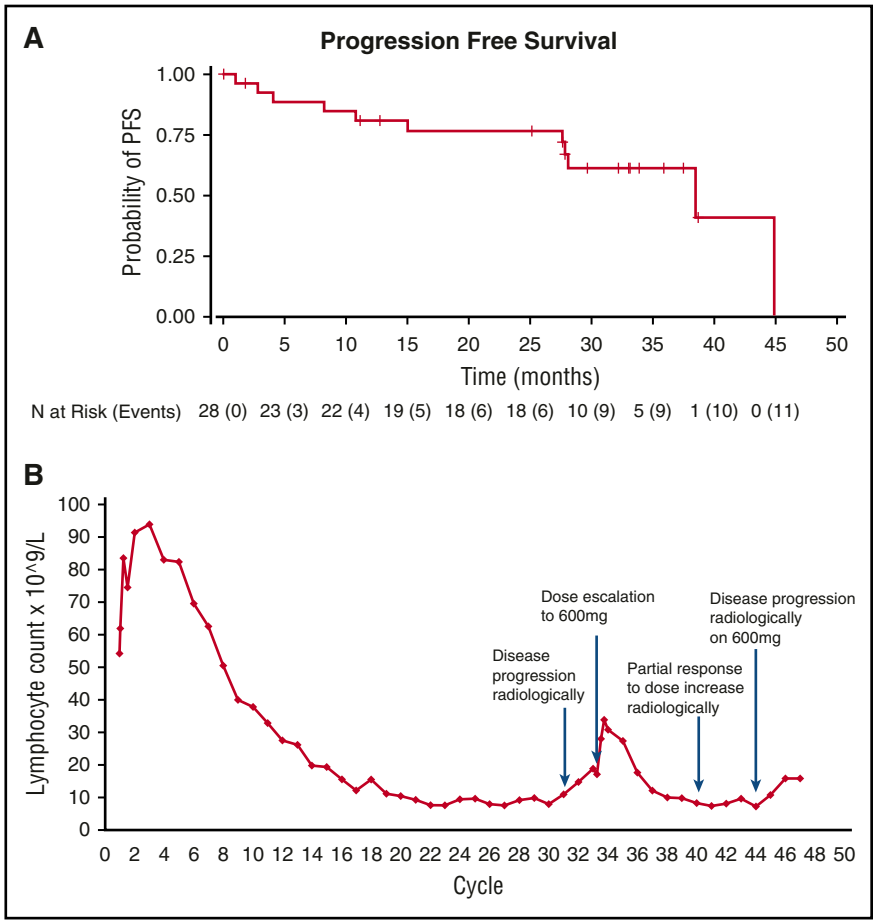

Figure 1. Updated results with ONO/GS-4059 in patients with CLL. (A) Updated PFS curve for CLL patients. Mean duration on study was 26.6 months and estimated median PFS was 38.5 months. (B) Case example: Recurrent lymphocytosis shown in *TP53* mutant CLL patient following an initial lymph nodal response for 31 cycles on 40 mg OD ONO/GS-4059; the patient subsequently responded for a further 12 months to 600 mg OD, with a second lymphocytosis (1.74-fold increase; initial 1.81-fold increase) and lymph nodal response.

Table 1. Updated TEAEs (frequency >15%) for CLL patients

AE	Grade 1-2 (%)	Grade 3-4 (%)	Total (%)
Bruising	10 (35.7)	0 (0)	10 (35.7)
Neutropenia	3 (10.7)	7 (25.0)	10 (35.7)
Nasopharyngitis	9 (32.1)	0 (0)	9 (32.1)
Anemia	6 (21.4)	3 (10.7)	9 (32.1)
Fall	9 (32.1)	0 (0)	9 (32.1)
Cough	8 (28.6)	0 (0)	8 (28.6)
Arthralgia	8 (28.6)	0 (0)	8 (28.6)
Basal cell carcinoma	8 (28.6)	0 (0)	8 (28.6)
Lower respiratory tract infection	3 (10.7)	4 (14.3)	7 (25.0)
Diarrhea	5 (17.9)	2 (7.1)	7 (25.0)
Pyrexia	6 (21.4)	1 (3.6)	7 (25.0)
Hematoma	6 (21.4)	1 (3.6)	7 (25.0)
Abdominal pain (upper and lower)	6 (21.4)	0 (0)	6 (21.4)
Herpes zoster infection	6 (21.4)	0 (0)	6 (21.4)
Constipation	6 (21.4)	0 (0)	6 (21.4)
Dry skin	6 (21.4)	0 (0)	6 (21.4)
Macules	6 (21.4)	0 (0)	6 (21.4)
Petechiae	5 (17.9)	1 (3.6)	6 (21.4)
Purpura	5 (17.9)	1 (3.6)	6 (21.4)
Oropharyngeal pain	6 (21.4)	0 (0)	6 (21.4)
Paraesthesia	6 (21.4)	0 (0)	6 (21.4)
Bronchitis	5 (17.9)	0 (0)	5 (17.9)
Vomiting	5 (17.9)	0 (0)	5 (17.9)
Erythema	5 (17.9)	0 (0)	5 (17.9)
Fatigue	5 (17.9)	0 (0)	5 (17.9)
Musculoskeletal pain	5 (17.9)	0 (0)	5 (17.9)
Thrombocytopenia	1 (3.6)	4 (14.3)	5 (17.9)

The ONO/GS-4059 POE001 phase 1 clinical study (NCT01659255) was conducted to determine the safety and tolerability of ONO/GS-4059 in patients with relapsed/refractory (R/R) B-cell malignancies. Between September 2012 and January 2015, 90 patients were enrolled and treated with ONO/GS-4059. Patients continuing to respond or those who have stable disease could enroll in the long-term extension study (ONO/GS-US-1787, NCT02457559). In the CLL cohort (comprising 28 patients), treatment consisted of 9 cohorts receiving 20 mg once daily to 600 mg once daily or a twice-daily regimen of 300 mg. Each site had Institutional Ethical Committee approval. Informed consent was obtained from all patients transferring to the extension study. DNA was extracted from peripheral blood from 27/28 CLL patients before trial therapy. Targeted sequencing was performed using the Illumina next-generation sequencing (NGS) platform from Sistemas Genomicos (Valencia, Spain), using a predesigned CLL panel (supplemental Table 1, available on the *Blood* Web site). Reads were aligned against the human reference genome version GRCh37/hg19. Filtering was performed using Picard tools (https://broadinstitute.github.io/picard/) and SAMtools (http://samtools.sourceforge.net/). Confirmatory Sanger sequencing was performed on identified sequence variants and annotated using the Ensembl database (www.ensembl.org). Only sequence variants leading to a change in amino acid composition and not reported in the single nucleotide polymorphism database were scored as mutations. Sanger sequencing was used to determine *IGHV* status. Statistical analysis was performed on the modified intention-to-treat population (patients with ≥1 dose of study drug). Kaplan-Meier methodology was used to calculate progression-free survival (PFS). The date of definitive progression was the time point at which progression was first identified by radiographic, imaging, or clinical data, or death. Patients were censored if no PFS event was observed.

All 28 patients enrolled with R/R CLL were evaluable for efficacy and safety. The median number of prior treatments was 4 (range 2-9); 5 patients were primarily fludarabine refractory, and 1 patient had received a prior PI3K inhibitor. Eleven patients (39%) were refractory to their last line of therapy. None had received prior BTKi treatment. Anticoagulant therapy was permitted; 6/28 patients were on anticoagulant therapy during the study. At the time of updated analysis (June 8, 2016), 11 patients (39.3%) had discontinued treatment. (In comparison, at 3 years, 47% had discontinued treatment with Ibrutinib.[13]) Reasons for discontinuation were death (n = 3), disease progression (n = 4), adverse events (AEs) (n = 3), and sponsor decision due to extended drug interruption (n = 1); in 1 patient with AE, disease progression occurred concurrently (supplemental Table 1). Subjects remaining on study were receiving doses of ONO/GS-4059 ranging from 40 mg once daily to 600 mg once daily or 300 mg twice daily. No maximum tolerated dose in patients with CLL was identified. The median duration on study at censoring was 32.5 months. Estimated median PFS was 38.5 months (Figure 1A), and median overall survival was 44.9 months.

Responses (complete or partial) were initially observed in 24/25 (96%) evaluable patients.[10] Ibrutinib can result in prolonged lymphocytosis (duration >1 year), reported in 20% of patients in the phase 1b/2 trial[14] and associated with 13q deletion. In our study, 23 patients (82%) exhibited lymphocytosis; mean fold increase above baseline was 4.5-fold.[10] In all instances, lymphocytosis following ONO/GS-4059 resolved by cycle 6. As with other BTKis,[11,15] changes in serum levels of CCL3 and CCL4 showed a significant decrease at day 8, consistent with B-cell receptor signaling pathway blockade; tumor necrosis factor-α, interleukin-10 (IL-10), IL-6, and IL-8 also showed a significant decrease 8 days after treatment initiation (supplemental Figure 1A). Similar to data reported with acalabrutinib[11] but in contrast to ibrutinib,[16] immunoglobulin levels did not change significantly with long-term therapy with ONO/GS-4059 (supplemental Figure 1B).

Targeted NGS mutational data at time of trial entry, along with *IGHV* mutation and interphase FISH data, are shown in supplemental Table 1. Twenty-one of 25 patients exhibited unmutated *IGHV* gene segments. Seven of 21 patients with unmutated *IGHV* gene segments have discontinued treatment. One patient with mutated *IGHV* utilizing V_H3-21 progressed. Although no formal correlative analysis was possible due to small sample size, no differences in response or PFS according to chromosome 17p deletion or *TP53* mutation were observed. Seven of 10 patients with *TP53* mutation remain on therapy; of the 3 that discontinued study treatment, 1 progressed, 1 was withdrawn due to an AE, and 1 died of septicemia. The patient with the *TP53* mutation who progressed with a *TP53* mutation in the DNA binding domain (DeltaL252T253) had an initial response for 31 cycles on a dose of 40 mg once daily ONO/GS-4059. Because this patient lacked *BTK* and *PLCG2* mutations (data not shown), the dose of ONO/GS-4059 was increased to 600 mg once daily. The patient responded for a further 12 months, associated with a second lymphocytosis comparable to that seen initially (1.74-fold increase; initial 1.81-fold increase) and lymph nodal response (Figure 1B). One of 3 patients with *ATM* mutation has progressed on study (930 days). Eight patients had *SF3B1* mutations, 5 of whom have discontinued treatment (1 due to progression). *NOTCH1* mutations were found in 7 patients, 3 of whom have come off study (1 due to progression). As previously reported, *NOTCH1* and *SF3B1* were mutually exclusive.[17] No mutations appeared to predict shorter PFS with ONO/GS-4059, but the sample sizes were too small for statistical analysis. Mutations not previously identified in CLL include a mutation in *MEK1* (E203K) in 1 patient with early progression, previously reported in metastatic melanoma resistant to vemurafenib,[18] and a *POT1* mutation E67K. No mutations in *MYD88*, *PLCG2*, or *BRAF* were observed.

ONO/GS-4059 continued to be well tolerated. Extended follow-up did not reveal new safety or toxicity concerns, and updated treatment-emergent AEs (TEAEs; frequency ≥15%) are shown in Table 1. Most

TEAEs were grade 1 or 2. The most common AEs were bruising (35.7% all grades), neutropenia (35.7% all grades), and anemia (32.1% all grades). Only 1 grade 3 bleeding event (3.6%; hematoma) occurred on study in a patient not receiving anticoagulation therapy. Twelve patients (42.9%) had greater than or equal to grade 3 infections. There were no greater than or equal to grade 3 events reported for other AEs of interest with the BTKi class, including hypertension and atrial fibrillation. One patient had an AE of weight gain; 14 patients (50%) had a grade 1 to 3 weight gain. Similar weight gain has been reported with acalabrutinib.[11]

Interestingly, no cases of Richter transformation have been reported in patients receiving ONO/GS-4059. Richter transformation in patients receiving ibrutinib tends to occur early.[8,19]

In conclusion, these data strongly support the ongoing evaluation of ONO/GS-4059 in CLL. Patients with high-risk CLL genetics responded with minimal toxicity. Identification of significant differences in toxicity profiles between BTKis awaits direct comparative studies. However, the tolerability of ONO/GS-4059 shown here with extended follow-up may confer advantages, particularly in the context of combination therapies and in ibrutinib-intolerant patients.

The online version of this article contains a data supplement.

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ORCID profiles: H.S.W., 0000-0003-2618-711X; S.J., 0000-0003-1870-9782; S.A.R., 0000-0001-8937-6351; F.M., 0000-0002-3714-9824; S. Macip, 0000-0003-1963-8840; C.F., 0000-0001-9685-0621; G.S., 0000-0002-9541-8666; M.J.S.D., 0000-0002-5033-2236.

Correspondence: Martin J. S. Dyer, University of Leicester, Henry Wellcome Building, Room 3/57, Lancaster Rd, Leicester LE1 9HN, United Kingdom; e-mail: mjsd1@le.ac.uk.

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