

ORIGINAL ARTICLE

Lenalidomide plus Dexamethasone for Relapsed Multiple Myeloma in North America

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ABSTRACT

BACKGROUND

Lenalidomide, an oral immunomodulatory drug that is similar to thalidomide but has a different safety profile, has clinical activity in relapsed or refractory multiple myeloma.

METHODS

Patients in the United States and Canada who had received at least one previous therapy for multiple myeloma but who required additional treatment were randomly assigned to receive either 25 mg of lenalidomide or placebo on days 1 to 21 of a 28-day cycle. Both groups also received 40 mg of oral dexamethasone on days 1 to 4, 9 to 12, and 17 to 20 for the first four cycles. After the fourth cycle, 40 mg of dexamethasone was administered only on days 1 to 4. Safety, clinical response, time to progression, and overall survival were assessed.

RESULTS

We assigned 177 patients to the lenalidomide group and 176 to the placebo group. Complete, near-complete, or partial responses occurred in 108 patients (61.0%) in the lenalidomide group and in 35 patients (19.9%) in the placebo group ($P<0.001$); complete responses occurred in 14.1% and 0.6%, respectively ($P<0.001$). The median time to progression was 11.1 months in the lenalidomide group and 4.7 months in the placebo group ($P<0.001$). Median overall survival times in the two groups were 29.6 months and 20.2 months, respectively ($P<0.001$). Grade 3 or 4 adverse events were reported in 85.3% of the lenalidomide group and in 73.1% of the placebo group; these events resulted in study discontinuation in 19.8% and 10.2%, respectively. Grade 3 or 4 neutropenia and venous thromboembolism were more common in the lenalidomide group than in the placebo group (41.2% vs. 4.6% and 14.7% vs. 3.4%, respectively; $P<0.001$ for both comparisons).

CONCLUSIONS

Lenalidomide plus dexamethasone is superior to placebo plus dexamethasone in patients with relapsed or refractory multiple myeloma. (ClinicalTrials.gov number, NCT00056160.)

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MULTIPLE MYELOMA CAUSES NEARLY 11,000 deaths annually in the United States.¹ Treatment with the immunomodulatory agent thalidomide or the proteasome inhibitor bortezomib has improved response rates, time to progression, and survival, but the side effects of fatigue, neuropathy, constipation, and thrombotic events remain a concern.²⁻⁶ In nearly all patients who receive these drugs or other chemotherapy, the disease eventually relapses and is subsequently resistant to treatment.

Lenalidomide is a thalidomide derivative that down-regulates interleukin-6 and nuclear factor κ -B and activates caspase 8 *in vitro*. The drug is up to 50,000 times as potent as its parent molecule in inhibiting tumor necrosis factor α .⁷ Phase 1 and 2 trials of lenalidomide in patients with treatment-refractory multiple myeloma showed a partial-response rate of 24 to 29%.⁸⁻¹⁰ Moreover, an additional 29% of patients who had not had a response to lenalidomide alone had a partial remission after the addition of pulsed doses of dexamethasone.¹⁰ We report here on a randomized, phase 3 trial that compared lenalidomide plus dexamethasone with placebo plus dexamethasone in patients with relapsed or refractory multiple myeloma.

METHODS

PATIENTS

Patients were eligible for the study if they were at least 18 years of age, had progressive multiple myeloma after at least one previous treatment, and had measurable disease that was not resistant to dexamethasone. Patients were considered to have disease that was resistant to dexamethasone if they had had progression during previous therapy containing high-dose dexamethasone (total monthly dose, >200 mg). Measurable disease was defined as a serum monoclonal protein (M protein) level of at least 0.5 g per deciliter or a urinary Bence Jones protein level of at least 0.2 g per day. Additional eligibility criteria included an Eastern Cooperative Oncology Group performance status of no more than 2, a serum aspartate aminotransferase or alanine aminotransferase level that was no more than 3 times the upper limit of the normal range, a serum bilirubin level that was no more than 2 times the upper limit of the normal range, a serum creatinine level of less than 2.5 mg per deciliter (221 μ mol per liter), an absolute neutrophil count of at least 1000 per cubic millime-

ter, and a platelet count of more than 75,000 per cubic millimeter for patients with less than 50% bone marrow plasma cells and more than 30,000 per cubic millimeter for patients with 50% or more bone marrow plasma cells. Women of childbearing potential were eligible if they agreed to use contraception, had a negative pregnancy test before enrollment, and agreed to undergo monthly pregnancy testing until 4 weeks after the discontinuation of the study drug.

STUDY DESIGN

In this multicenter, double-blind, placebo-controlled, randomized, phase 3 trial, patients received 25 mg of daily oral lenalidomide or placebo on days 1 to 21 of each 28-day cycle. All patients also received 40 mg of daily oral dexamethasone on days 1 to 4, 9 to 12, and 17 to 20. After the fourth cycle, 40 mg of dexamethasone was administered only on days 1 to 4. Treatment was continued until the occurrence of disease progression or unacceptable toxic effects. Central randomization was performed with a block size of 4 and the use of an integrated voice-response system. The assignment of patients was stratified according to the level of serum β_2 -microglobulin (<2.5 mg per liter vs. \geq 2.5 mg per liter), previous stem-cell transplantation (none vs. \geq 1), and the number of previous antimyeloma therapies (1 vs. \geq 2).

The primary end point was the time to disease progression. Secondary end points included overall survival and the response rate.

Toxic effects were graded according to the National Cancer Institute's Common Toxicity Criteria, version 2.¹¹ In the case of a grade 3 or 4 adverse event, treatment was withheld and restarted at the next lower daily dose. The dose of lenalidomide was modified as follows: 15 mg (dose level, -1), 10 mg (dose level, -2), or 5 mg (dose level, -3). For grade 3 or 4 neutropenia without other toxic effects, the first dose-modification step was dose level -1 (daily subcutaneous injection of 5 μ g of granulocyte colony-stimulating factor per kilogram of body weight and 25 mg of lenalidomide); sequential dose reductions of lenalidomide were 15 mg (dose level, -2), 10 mg (dose level, -3), and 5 mg (dose level, -4) plus the daily administration of 5 μ g per kilogram of granulocyte colony-stimulating factor at the investigator's discretion. Thromboprophylaxis was not required, although it was used on an individual basis. Modifications in the dose of dexamethasone because of toxic effects were 40 mg daily for 4 days

every 2 weeks (dose level, -1) or every 4 weeks (dose level, -2) or 20 mg daily for 4 days every 4 weeks (dose level, -3).

Blood counts and physical examination were performed on days 1 and 15 (and day 8 of cycle 1) during cycles 1 to 3 and on day 1 of each cycle thereafter. Serum and urinary protein electrophoresis studies were performed on day 1 of each cycle and at the end of treatment. Survival status was determined every 6 months after the discontinuation of treatment.

The study was designed as a collaborative effort by Dr. Weber, the coinvestigators, and the sponsor, Celgene. The sponsor collected the data and performed the final analysis in collaboration with an independent data monitoring committee and Dr. Weber. All authors had full access to the primary data and the final analysis. Dr. Weber wrote the first draft of the manuscript and vouches for the completeness and accuracy of the clinical results and the reporting of adverse events. An independent data and safety monitoring committee reviewed ongoing safety and efficacy data throughout the study.

RESPONSE CRITERIA

The response of patients was assessed according to the criteria of the European Group for Blood and Marrow Transplantation.¹² A partial response was defined as a reduction of M protein by at least 50% in serum, 90% in urine, or both, as confirmed by at least two electrophoretic measurements. A complete response was defined as the complete disappearance of M protein in serum and urine by immunofixation, as confirmed by two measurements, and the presence of less than 5% marrow plasma cells; the criteria for near-complete remission were identical to those for complete remission but without confirmation of marrow plasmacytosis of less than 5% or the disappearance of M protein.

The time to progression was measured from randomization to the date of the first assessment showing disease progression. Progressive disease was defined as an increase of at least 25% in M protein from nadir; an absolute increase in serum M protein of more than 500 mg per deciliter, as compared with the nadir value; an absolute increase in urinary M protein of more than 200 mg per 24-hour period; or either a new bone lesion or plasmacytoma (or an increase in the size of such lesions), or a serum calcium level of more than 11.5 mg per deciliter (2.9 mmol per liter).

Table 1. Demographic and Clinical Characteristics of the Patients.*

Characteristic	Lenalidomide (N=177)	Placebo (N=176)
Age — yr		
Median	64	62
Range	36–86	37–85
Male sex — %	59.9	59.1
Time since diagnosis — yr		
Median	3.1	3.1
Range	0.5–14.7	0–19.7
Durie–Salmon stage — no. (%)		
I	6 (3.4)	5 (2.8)
II	56 (31.6)	55 (31.2)
III	114 (64.4)	116 (65.9)
Missing data	1 (0.6)	0
Eastern Cooperative Oncology Group performance status — no. (%)†		
0	74 (41.8)	83 (47.2)
1	83 (46.9)	80 (45.5)
2	14 (7.9)	6 (3.4)
Missing data	6 (3.4)	7 (4.0)
Previous therapy — no. (%)		
No. of therapies		
1	68 (38.4)	67 (38.1)
≥2	109 (61.6)	109 (61.9)
Type of therapy		
Thalidomide	74 (41.8)	80 (45.5)
Bortezomib	19 (10.7)	20 (11.4)
Stem-cell transplantation	109 (61.6)	108 (61.4)
β ₂ -microglobulin level — no. (%)		
<2.5 mg per liter	52 (29.4)	51 (29.0)
≥2.5 mg per liter	125 (70.6)	125 (71.0)

* There were no significant differences between the two groups according to a pooled t-test for continuous variables (age and time since first pathological diagnosis) and Fisher's exact test for categorical variables (all other variables in the table) ($P>0.05$). Percentages may not total 100 because of rounding.

† Lower numbers indicate better performance.

Data for patients who died before there was evidence of disease progression were censored at the time of the last evaluation for assessment of time to progression. Overall survival was calculated as the time from randomization until death from any cause or the date of the last visit.

STATISTICAL ANALYSIS

The number of patients was calculated so that a one-sided log-rank test at the 0.025 level, allowing

Table 2. Response among Patients in the Intention-to-Treat Population and in Selected Subgroups.

Variable	Lenalidomide (N=177)	Placebo (N=176)	P Value*
Response in the intention-to-treat population — no. (%)			
Overall response	108 (61.0)	35 (19.9)	<0.001
Complete response	25 (14.1)	1 (0.6)	<0.001
Near-complete response	18 (10.2)	2 (1.1)	
Partial response	65 (36.7)	32 (18.2)	
Stable disease	54 (30.5)	102 (58.0)	
Progressive disease	5 (2.8)	25 (14.2)	
Response could not be evaluated	10 (5.6)	14 (8.0)	
Overall response in selected subgroups — no./total no. (%)†			
Previous use of thalidomide			
Yes	42/74 (56.8)	10/80 (12.5)	<0.001
No	66/103 (64.1)	25/96 (26.0)	<0.001
Previous use of bortezomib			
Yes	13/19 (68.4)	2/20 (10.0)	<0.001
No	95/158 (60.1)	33/156 (21.2)	<0.001
β_2 -microglobulin level			
<2.5 mg per liter	39/52 (75.0)	14/51 (27.5)	<0.001
\geq 2.5 mg per liter	69/125 (55.2)	21/125 (16.8)	<0.001
Previous no. of therapies			
1	44/68 (64.7)	15/67 (22.4)	<0.001
\geq 2	64/109 (58.7)	20/109 (18.3)	<0.001
Previous stem-cell transplantation			
Yes	72/109 (66.1)	21/108 (19.4)	<0.001
No	36/68 (52.9)	14/68 (20.6)	<0.001

* P values were calculated with the use of a continuity-corrected Pearson chi-square test.

† There was no stratum-by-treatment interaction for response rates with the use of the Breslow–Day test for homogeneity. Percentages are for the rate of overall response among patients within selected subgroups of the intention-to-treat population.

for one interim analysis, would have a statistical power of 85% to detect a difference between the time to progression for each group with a constant hazard ratio of 1.5, reflecting an increase of 50% in the median time to progression. The number of events required was 222. On the basis of the planned accrual rate, a log-rank test of overall survival that was performed 18 months after the last patient had been enrolled, when 194 deaths were expected, would have a power of 80% to detect a hazard ratio for death of 0.67. An interim analysis to evaluate safety and efficacy was planned

when 111 patients had disease progression; if the predetermined O'Brien–Fleming boundary for the superiority of lenalidomide over placebo was crossed, the study would be unblinded and patients would be allowed to cross over to open-label administration of lenalidomide at progression or at the investigator's discretion.

All primary analyses were based on the intention-to-treat population, and subgroup analyses were planned on the basis of stratification variables. An unstratified log-rank test was used to compare the time-to-event variables between the two study groups. Both the time to progression and overall survival were estimated by Kaplan–Meier methods, and a Cox proportional-hazards regression model was used to assess the effect of demographic and prognostic variables on differences in treatment responses between the two study groups. Exact tests were used to compare response rates. All reported P values are two-sided.

RESULTS

PATIENTS

From February 27, 2003, to April 14, 2004, a total of 353 patients were enrolled at 44 centers in the United States and 4 in Canada. Of those patients, 177 were assigned to receive lenalidomide plus dexamethasone (lenalidomide group) and 176 to receive placebo plus dexamethasone (placebo group). Baseline characteristics were well balanced between the two groups (Table 1). Previous treatments included radiotherapy, myeloablative therapy with stem-cell transplantation, and various combinations of dexamethasone, melphalan, doxorubicin, thalidomide, bortezomib, and other chemotherapy agents.

Because the O'Brien–Fleming boundary for the superiority of lenalidomide over placebo was crossed at the interim analysis, the data and safety monitoring committee recommended that the study be unblinded. The results presented here for response and time to progression are based on data obtained before unblinding, and the results for safety are based on data obtained before December 31, 2005. Median follow-up was 17.6 months.

RESPONSE RATE

Among 177 patients in the lenalidomide group, 108 (61.0%) had a response (complete, near-complete, or partial), as compared with 35 of 176 patients (19.9%) in the placebo group ($P<0.001$)

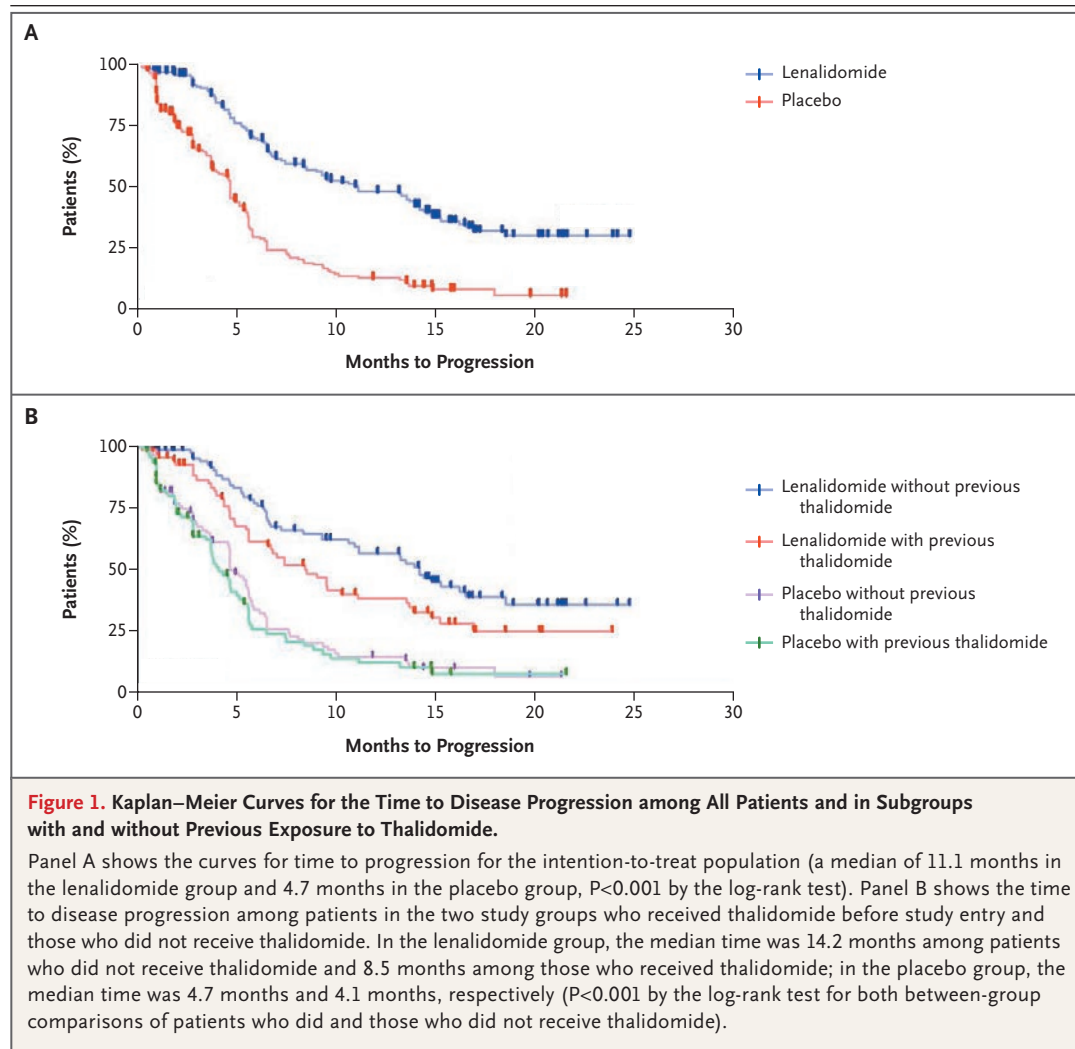
(Table 2). A complete response occurred in 25 patients (14.1%) in the lenalidomide group and in 1 patient (0.6%) in the placebo group ($P<0.001$); a near-complete response occurred in 18 patients (10.2%) in the lenalidomide group and in 2 patients (1.1%) in the placebo group ($P<0.001$). The median time to a response was similar in the two groups, but the median duration of the response was significantly longer in the lenalidomide group than for those in the placebo group (15.8 months vs. 5.1 months, $P<0.001$). The overall response rate was higher for patients who received lenalidomide, regardless of the stratification group (Table 2). In addition, previous treatment with thalidomide did not affect the response to lenalidomide; 56.8% of patients who had received thalidomide had a complete, near-complete, or partial response, as compared with 64.1% who had not received

thalidomide ($P=0.33$). Similarly, previous treatment with bortezomib did not affect the response to lenalidomide (Table 2).

TIME TO PROGRESSION

The median time to progression was significantly longer in the lenalidomide group (11.1 months) than in the placebo group (4.7 months), with a hazard ratio of 0.35 (95% confidence interval [CI], 0.27 to 0.47; $P<0.001$) (Fig. 1A). The median time to progression was significantly larger in all subgroups of patients who received lenalidomide, as compared with those who received placebo ($P<0.001$ for all comparisons), including patients who had received one previous therapy (median time not reached vs. 5.1 months) or two or more previous therapies (10.2 months vs. 4.6 months).

Among the 154 patients who had been ex-



posed to thalidomide, the median time to progression was also significantly improved in the lenalidomide group (8.5 months), as compared with the placebo group (4.1 months, $P < 0.001$) (Fig. 1B). The median time to progression did not differ significantly between patients who had been exposed to thalidomide and those who had not been exposed to thalidomide ($P = 0.08$). The median time to progression among the 39 patients who had received previous treatment with bortezomib was longer in the lenalidomide group (10.3 months) than in the placebo group (3.3 months, $P < 0.001$).

In the two study groups, prognostic factors for significant improvement in the time to progression were a serum β_2 -microglobulin level of less than 2.5 mg per liter, only one previous antimyeloma therapy, and a lower baseline level of bone marrow plasmacytosis, according to Cox regression analysis.

SURVIVAL

As of May 2006, a total of 49 patients (27.7%) had died in the lenalidomide group (40 from progressive disease), as had 63 patients (35.8%) in the placebo group (53 from progressive disease). The

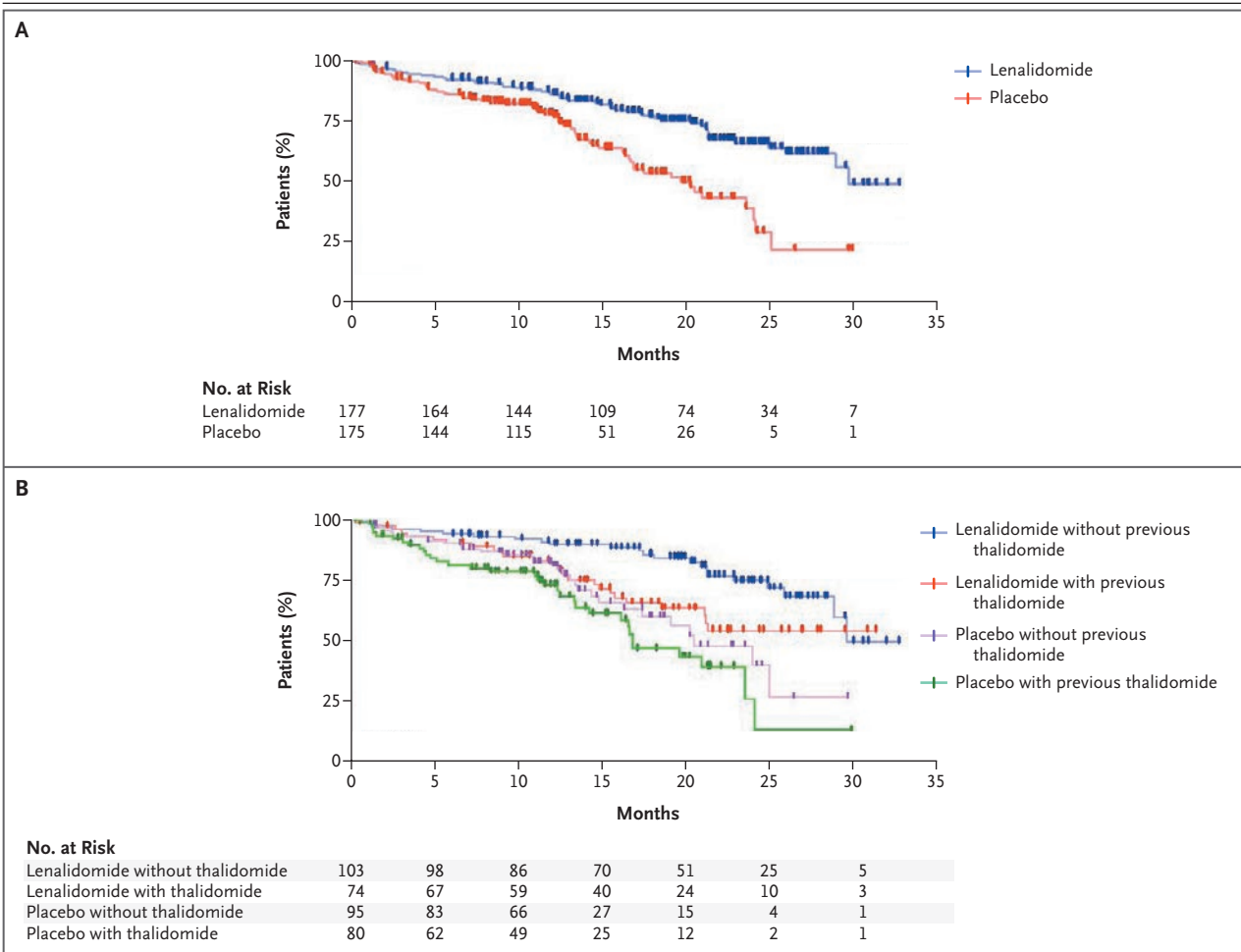


Figure 2. Kaplan–Meier Curves for Overall Survival for All Patients and in Subgroups with and without Previous Exposure to Thalidomide.

Panel A shows the curves for overall survival for the intention-to-treat population (a median of 29.6 months in the lenalidomide group and 20.2 months in the placebo group, $P < 0.001$ by the log-rank test). Panel B shows the overall survival among patients in the two study groups who received thalidomide before study entry and those who did not receive thalidomide. In the lenalidomide group, the median time was 29.6 months among those who did not receive thalidomide, and the median was not yet reached among those who received thalidomide; in the placebo group, the median time was 20.5 months among those who did not receive thalidomide and 16.8 months among those who received thalidomide ($P < 0.001$ by the log-rank test for the between-group comparison of patients who did not receive thalidomide and $P = 0.03$ for the between-group comparison of patients who received thalidomide).

median follow-up from randomization to data cutoff for the surviving patients was 26.2 months in the lenalidomide group and 12.9 months in the placebo group. The median overall survival was significantly longer for patients in the lenalidomide group (29.6 months) than for those in the placebo group (20.2 months), with a hazard ratio of 0.44 (95% CI, 0.30 to 0.65; $P < 0.001$) (Fig. 2A). Overall survival was also significantly improved in the lenalidomide group, as compared with the placebo group, among patients who had been treated with thalidomide (hazard ratio, 0.56; 95% CI, 0.34 to 0.95; $P = 0.03$) (Fig. 2B).

ADVERSE EVENTS

The most frequently reported nonhematologic adverse events were fatigue, insomnia, diarrhea, constipation, muscle cramps, and infection. Infections were more common in the lenalidomide group than in the placebo group (67.8% vs. 44.0%, $P < 0.001$) but were usually grade 2 or less; grade 3 or 4 infections were noted in 38 patients (21.5%) and 21 patients (12.0%), respectively ($P = 0.14$) (Table 3). Among patients with grade 3 or 4 infections in the lenalidomide group and the placebo group, 31 and 17 patients, respectively, required antibiotics; 3 and 1, respectively, required antiviral therapy; and 3 and 4, respectively, required antifungal therapy. The most frequently reported infections were upper respiratory tract infections and pneumonia. In the lenalidomide group, grade 3 or 4 peripheral neuropathy, constipation, and diarrhea developed in 1.7%, 2.8%, and 3.4% of patients, respectively (Table 3).

Venous thromboembolic events were more common in the lenalidomide group than in the placebo group (14.7% vs. 3.4%, $P < 0.001$). There were no deaths due to venous thromboembolic events. The dose of lenalidomide was reduced in seven patients, and eight stopped treatment after the event. In a post hoc analysis among 98 patients in the lenalidomide group who were receiving concurrent epoetin alfa or darbepoetin, 18.4% had thrombotic events, as compared with 10.1% of patients not receiving these agents ($P = 0.14$). In the placebo group, among patients with and those without concomitant administration of these drugs, thromboembolic complications occurred in 5 of 69 patients (7.2%) and 1 of 106 patients (0.9%), respectively ($P = 0.04$).

Grade 3 or 4 hematologic toxic effects occurred in 52.5% of patients in the lenalidomide

group and in 13.7% of patients in the placebo group ($P < 0.001$). Grade 3 or 4 neutropenia was more common in the lenalidomide group (41.2%) than in the placebo group (4.6%, $P < 0.001$), as was thrombocytopenia (14.7% vs. 6.9%, $P = 0.02$).

Sixty-eight patients (38.4%) in the lenalidomide group and 126 patients (71.6%) in the placebo group discontinued the study drug because of disease progression, and 35 (19.8%) and 18 (10.2%), respectively, discontinued the study drug because of adverse events. The proportion of patients who required at least one dose reduction or interruption of a study drug because of adverse events was higher in the lenalidomide group than in the placebo group (76.8% vs. 57.7%). There were four deaths that were considered to be possibly related to a study drug: three in the lenalidomide group (two from sepsis and one from a cerebrovascular accident) and one in the placebo group (pneumonia). Neutropenia and thrombocytopenia were the primary reasons for dose reduction in the lenalidomide group, but less than 5% of patients had neutropenia or thrombocytopenia resulting in discontinuation of the study drug. The median time to the first dose reduction or interruption was approximately 2 months in the two study groups.

Granulocyte colony-stimulating factor was administered if grade 3 or 4 myelosuppression occurred without the occurrence of other adverse events; with additional grade 3 or 4 adverse events, the dose of lenalidomide was reduced. Among the 177 patients in the lenalidomide group, 60 (33.9%) received granulocyte colony-stimulating factor during the study. Among these 60 patients, 28 (46.7%) received granulocyte colony-stimulating factor as the first step in dose reduction because of grade 3 or 4 neutropenia, to maintain the 25-mg dose level. Among these 28 patients, 12 (42.9%) were able to continue with the 25-mg dose level of lenalidomide. The dose of dexamethasone was reduced in 31.1% of patients receiving lenalidomide and in 15.4% receiving placebo.

DISCUSSION

In our randomized phase 3 study, we found that lenalidomide plus dexamethasone had significant clinical activity in patients with relapsed or refractory multiple myeloma. Lenalidomide plus dexamethasone was superior to high-dose dexamethasone alone in terms of the overall response

Table 3. Grade 3 or 4 Adverse Events (Safety Population).*

Event	Lenalidomide (N=177)		Placebo (N=175)	
	Grade 3	Grade 4	Grade 3	Grade 4
	<i>number (percent)</i>			
Hematologic disorder				
Neutropenia	62 (35.0)	11 (6.2)	6 (3.4)	2 (1.1)
Anemia	19 (10.7)	4 (2.3)	6 (3.4)	3 (1.7)
Thrombocytopenia	24 (13.6)	2 (1.1)	12 (6.9)	0
Febrile neutropenia	5 (2.8)	1 (0.6)	0	0
Gastrointestinal disorder				
Diarrhea	6 (3.4)	0	0	0
Constipation	5 (2.8)	0	0	0
Nausea	5 (2.8)	0	2 (1.1)	0
Dyspepsia	1 (0.6)	0	1 (0.6)	0
General and administration-site disorder				
Fatigue	11 (6.2)	0	11 (6.3)	0
Peripheral edema	4 (2.3)	0	1 (0.6)	0
Pyrexia	4 (2.3)	0	6 (3.4)	0
Asthenia	6 (3.4)	0	6 (3.4)	0
Infection or infestation				
Any infection†	33 (18.6)	5 (2.8)	16 (9.1)	5 (2.9)
Upper respiratory infection	2 (1.1)	0	2 (1.1)	0
Pneumonia	19 (10.7)	3 (1.7)	10 (5.7)	3 (1.7)
Metabolism or nutrition disorder				
Hyperglycemia	15 (8.5)	4 (2.3)	10 (5.7)	5 (2.9)
Hypokalemia	10 (5.6)	1 (0.6)	2 (1.1)	0
Anorexia	1 (0.6)	0	3 (1.7)	0

rate (61.0% vs. 19.9%, $P<0.001$), median time to progression (11.1 months vs. 4.7 months, $P<0.001$), and median overall survival (29.6 months vs. 20.2 months, $P<0.001$). It is notable that patients with multiple myeloma that was refractory to standard treatments had a median time to progression of more than 10 months. In addition, there was a prolongation of overall survival. This benefit was evident even though 58.0% of patients in the placebo group later received lenalidomide or lenalidomide plus dexamethasone after disease progression or after the unblinding of the trial but were analyzed on an intention-to-treat basis in the placebo group.

The superior results with lenalidomide were observed regardless of the number of previous therapies, the serum β_2 -microglobulin level, or the history with respect to treatment with thalidomide or bortezomib. Response rates were higher in subgroups with a β_2 -microglobulin level of less

than 2.5 mg per liter and only one previous anti-myeloma therapy, suggesting that treatment early in the course of disease may also be beneficial. Most results of treatment with lenalidomide plus dexamethasone were superior even among patients treated previously with thalidomide. However, the shorter time to progression in these patients suggests some degree of cross-resistance between lenalidomide and thalidomide. Further trials of the clinical activity of lenalidomide in patients with established resistance to thalidomide should clarify this question of cross-resistance.

Neutropenia and thromboembolic events were more common in the lenalidomide group than in the placebo group. Neutropenia was managed with dose adjustments, the administration of granulocyte colony-stimulating factor, or both, and thromboembolic events were managed with anticoagulants. Grade 3 or 4 myelosuppression was more common in patients who received lena-

Table 3. (Continued.)

Event	Lenalidomide (N=177)		Placebo (N=175)	
	Grade 3	Grade 4	Grade 3	Grade 4
	<i>number (percent)</i>			
Musculoskeletal or connective-tissue disorder				
Muscle cramp	2 (1.1)	0	1 (0.6)	0
Back pain	2 (1.1)	0	3 (1.7)	0
Arthralgia	1 (0.6)	0	4 (2.3)	0
Muscle weakness	7 (4.0)	0	3 (1.7)	0
Nervous system disorder				
Headache	2 (1.1)	0	0	0
Dizziness	6 (3.4)	0	2 (1.1)	0
Tremor	0	0	2 (1.1)	0
Peripheral neuropathy	3 (1.7)	0	2 (1.1)	0
Psychiatric disorder				
Insomnia	2 (1.1)	0	0	0
Anxiety	4 (2.3)	0	0	0
Respiratory, thoracic, or mediastinal disorder				
Nasopharyngitis	1 (0.6)	0	0	0
Dyspnea	2 (1.1)	3 (1.7)	7 (4.0)	0
Skin or subcutaneous-tissue disorder				
Rash	1 (0.6)	0	0	0
Vascular disorder				
Deep-vein thrombosis	21 (11.9)	0	6 (3.4)	0
Pulmonary embolism	1 (0.6)	5 (2.8)	0	1 (0.6)
Venous thromboembolism‡	21 (11.9)	5 (2.8)	5 (2.9)	1 (0.6)

* Listed are data that were available on December 31, 2005.

† This condition was also described in the following terms: infections not otherwise specified, pneumonia, upper respiratory tract infection, upper respiratory viral infection, sepsis, bacterial infection, urinary tract infection, pharyngitis, nasopharyngitis, febrile neutropenia, oral candidiasis, oral fungal infection, primary atypical pneumonia, fungal sinusitis, herpes simplex, herpes zoster, herpes encephalitis, herpes viral infection, cytomegalovirus pneumonia, and viral infection.

‡ This condition was also described in the following terms: deep-vein thrombosis, pulmonary embolism, pulmonary infarction, thrombosis, phlebothrombosis, thrombophlebitis, superficial thrombophlebitis, venous thrombosis, thromboembolism, splenic-vein thrombosis, phlebitis, and superficial phlebitis.

lidomide plus dexamethasone in our study than in patients with relapsed or refractory multiple myeloma who received thalidomide plus dexamethasone or those with newly diagnosed disease who received lenalidomide plus dexamethasone in previous studies.^{2-4,13} In our study, grade 3 or 4 infections were noted in 21.5% of patients treated with lenalidomide, so future study of treatment or prophylaxis with granulocyte colony-stimulating factor, prophylaxis with oral broad-spectrum bacterial antibiotics, or both may be warranted. The low incidence of preventable grade 3 or 4 viral and fungal infections in our study does not support routine prophylaxis for these

infections in all patients. Constipation and diarrhea, generally mild to moderate in severity, affected 31.4% and 35.9% of patients, respectively. Lenalidomide differs from thalidomide in that it is associated with a low incidence of grade 3 or 4 sedation, fatigue, rash, and neuropathy.²⁻⁴

Our experience suggests that prophylactic anti-thrombotic therapy is warranted in patients who receive lenalidomide plus high-dose dexamethasone, although we did not test such a regimen. Grade 3 or 4 thromboembolic events occurred more frequently in the lenalidomide group than in the placebo group (14.7% vs. 3.4%, $P < 0.001$). In the Eastern Cooperative Oncology Group trial

of lenalidomide and high-dose dexamethasone in previously untreated patients, the frequency of thrombotic events was 22.1%.¹⁴ Recently, a phase 2 trial of lenalidomide and high-dose dexamethasone¹³ showed that only 3% of patients who received prophylaxis with aspirin had thrombotic events, although other studies have reported conflicting results.^{14,15} In our trial, the incidence of thromboembolic events in patients receiving concomitant epoetin alfa or darbepoetin was 18.4%. Thus, it is reasonable to suggest that concomitant erythropoietic agents be avoided.

In conclusion, the combination of lenalidomide and dexamethasone is effective in increas-

ing the response rate, time to progression, and overall survival in patients with relapsed or refractory myeloma.

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APPENDIX

In addition to the authors, the following investigators, listed in alphabetical order, participated in the Multiple Myeloma (009) Study: R. Abonour, Indiana Cancer Research Institute, Indianapolis; M. Alsina, H. Lee Moffitt Cancer Center, Tampa, FL; K. Barton, Loyola University Medical Center, Maywood, IL; L. Bertoli, Clinical Research Consultants, Hoover, AL; A. Brown, Ochsner Clinical Foundation, New Orleans; H. Burris, Sarah Cannon Cancer Center, Nashville; L. Chu, Oncology Hematology Consultants, Sarasota, FL; S. Coutre, Stanford Cancer Center, Stanford, CA; C. de Castro, Duke University Medical Center, Durham, NC; T. Dobbs, Baptist Regional Cancer Center, Knoxville, TN; S. Farag, Ohio State University, Columbus; H. Fernandez, University of Miami Sylvester Cancer Center, Miami; G. Geils, Jr., Charleston Hematology/Oncology, Charleston, SC; T. Gentile, SUNY Upstate Medical University, Syracuse, NY; S.A. Gregory, Rush University Medical Center, Chicago; D. Hurd, Wake Forest University School of Medicine, Winston-Salem, NC; S. Jagannath, St. Vincent's Comprehensive Cancer Center, New York; A.J. Jakubowiak, University of Michigan, Ann Arbor; A. Kutlar, Medical College of Georgia, Augusta; R. Lambert-Falls, South Carolina Oncology Associates, Columbia; T. Martin, University of California San Francisco, San Francisco; J. Moreb, University of Florida, Gainesville; A. Aspitia Moreno, Mayo Clinic, Jacksonville, FL; P. Richardson, Dana-Farber Cancer Institute, Boston; G.D. Roodman, Veterans Affairs Pittsburgh Health Care System, Pittsburgh; G. Schiller, University of California Los Angeles School of Medicine, Los Angeles; S. Seropian, Yale University School of Medicine, New Haven, CT; C. Shustik, McGill University, Montreal; M. Silverman-DeMagalhaes, University of Iowa Hospital and Clinic, Iowa City; S. Singhal, Northwestern University Medical Center, Chicago; G. Somlo, City of Hope National Medical Center, Duarte, CA; R. Stuart, Medical University of South Carolina, Charleston; N. Tirumali, Kaiser Permanente Northwest Region Center for Health Research, Portland, OR; R. Vij, Siteman Cancer Center, St. Louis; J.C. Wade, Medical College of Wisconsin, Milwaukee; D. White, Queen Elizabeth II Health Services Centre, Halifax, NS, Canada; P. Wiernik, New York Medical Center, Bronx, NY; J. Zonder, Wayne State University, Detroit.

REFERENCES

- American Cancer Society. Cancer facts and figures 2005. Atlanta: American Cancer Society, 2005.
- Singhal S, Mehta J, Desikan R, et al. Antitumor activity of thalidomide in refractory multiple myeloma. *N Engl J Med* 1999;341:1565-71. [Erratum, *N Engl J Med* 2000;342:364.]
- Rajkumar SV, Hayman S, Gertz MA, et al. Combination therapy with thalidomide plus dexamethasone for newly diagnosed myeloma. *J Clin Oncol* 2002;20:4319-23.
- Weber D, Rankin K, Gavino M, Delasalle K, Alexanian R. Thalidomide alone or with dexamethasone for previously untreated multiple myeloma. *J Clin Oncol* 2003;21:16-9.
- Richardson PG, Barlogie B, Berenson J, et al. A phase 2 study of bortezomib in relapsed, refractory myeloma. *N Engl J Med* 2003;348:2609-17.
- Richardson PG, Sonneveld P, Schuster MW, et al. Bortezomib or high-dose dexamethasone for relapsed multiple myeloma. *N Engl J Med* 2005;352:2487-98.
- Hideshima T, Chauhan D, Shima Y, et al. Thalidomide and its analogs overcome drug resistance of human multiple myeloma cells to conventional therapy. *Blood* 2000;96:2943-50.
- Zangari MTG, Zeldis J, Eddlemon P, Saghafifar F, Barlogie B. Results of phase I study of CC-5013 for the treatment of multiple myeloma (mm) patients who relapse after high dose chemotherapy (HDCT). *Blood* 2001;98:775a. abstract.
- Richardson PG, Schlossman RL, Weller E, et al. Immunomodulatory drug CC-5013 overcomes drug resistance and is well tolerated in patients with relapsed multiple myeloma. *Blood* 2002;100:3063-7.
- Richardson PG, Blood E, Mitsiades CS, et al. A randomized phase 2 study of lenalidomide therapy for patients with relapsed or relapsed and refractory multiple myeloma. *Blood* 2006;108:3458-64.
- National Cancer Institute. Common toxicity criteria v2.0 (CTC). (Accessed October 26, 2007, at http://ctep.cancer.gov/reporting/ctc_archive.html.)
- Bladé J, Samson D, Reece D, et al. Criteria for evaluating disease response and progression in patients with multiple myeloma treated by high-dose therapy and haemopoietic stem cell transplantation. *Br J Haematol* 1998;102:1115-23.
- Rajkumar SV, Hayman SR, Lacy MQ, et al. Combination therapy with lenalidomide plus dexamethasone (Rev/Dex) for newly diagnosed myeloma. *Blood* 2005;106:4050-3.
- Rajkumar SV, Jacobus S, Callander N, et al. Phase III trial of lenalidomide plus high-dose dexamethasone versus lenalidomide plus low-dose dexamethasone in newly diagnosed multiple myeloma (E4A03): a trial coordinated by the Eastern Cooperative Oncology Group. *J Clin Oncol* 2007;25:Suppl:18S. abstract.
- Zonder JA, Barlogie B, Durie BG, McCoy J, Crowley J, Hussein MA. Thrombotic complications in patients with newly diagnosed multiple myeloma treated with lenalidomide and dexamethasone: benefit of aspirin prophylaxis. *Blood* 2006;108:403.

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