A significant need exists for effective and well-tolerated treatments for patients with hematologic malignancies. Bendamustine hydrochloride is a novel cytotoxic agent that possesses alkylator and purine-like structural groups, which may confer a unique mechanism of action. Bendamustine recently was approved by the U.S. Food and Drug Administration for the treatment of chronic lymphocytic leukemia (CLL) and currently is being used in clinical trials for a number of hematologic and solid tumors. Bendamustine has demonstrated promising clinical activity in patients with hematologic malignancies and has manageable toxicities when administered as monotherapy or in combination with other agents. In clinical trials, nausea, fatigue, vomiting, fever, diarrhea, constipation, and headache were the most commonly reported nonhematologic side effects. Reversible myelosuppression also was reported. Nurses need to understand the efficacy and safety profiles of bendamustine to educate patients and their families about its use and expected side effects. Knowledge of specific measures for preventing and managing associated side effects and dose modifications is integral to the provision of optimal care.

Bendamustine: A Novel Cytotoxic Agent for Hematologic Malignancies

Susan Blumel, RN, BSN, OCN®, Amy Goodrich, CRNP, Cheryl Martin, MSN, NP, OCN®, and Nam H. Dang, MD, PhD

Bendamustine hydrochloride (Treanda®, Cephalon, Inc.) is a novel bifunctional mechlorethamine derivative approved in March 2008 by the U.S. Food and Drug Administration (FDA) for the treatment of patients with chronic lymphocytic leukemia (CLL) (Cephalon, Inc., 2008). Trials in the United States recently have been completed studying its use as monotherapy (Friedberg et al., 2008) and in combination with rituximab in patients with relapsed or refractory non-Hodgkin lymphoma (NHL) (Robinson et al., 2008). It currently is under FDA review for the treatment of patients with indolent NHL who have progressed during or following treatment with rituximab or a rituximab-containing regimen. Bendamustine also is under investigation for the treatment of multiple myeloma (MM) and solid tumors. Bendamustine originally was developed in 1963 in the former German Democratic Republic with the intention of producing an agent with alkylating and antimetabolite properties. German investigators first used bendamustine to treat MM in 1969 (Anger, Hesse, & Baufeld, 1969). From 1971–1992, it was marketed under the trade name Cytostasan® (IMET3393) by Jenapharm and currently is marketed in Germany as Ribomustin® by MundiPharma International Ltd., whereas in North America, bendamustine is being developed as Treanda by Cephalon, Inc.

Pharmacology

Bendamustine has a unique chemical structure. Similar to other alkylators, bendamustine contains a mechlorethamine (nitrogen mustard) alkylating group (see Figure 1); however, it also contains a benzimidazole ring. The effect of the benzimidazole ring on the clinical activity of bendamustine currently is unknown.

Bendamustine’s antitumor effects include DNA damage through double- and single-strand DNA cross-links and down-regulation of mitotic checkpoint genes that regulate DNA synthesis and cell division (Leoni et al., 2008). The concomitant activity of these mechanistic pathways may further increase the cytotoxicity of bendamustine through a process
At a Glance

- Bendamustine is a novel bifunctional mechlorethamine derivative that acts primarily as an alkylating agent. It is approved for use in the United States for the treatment of chronic lymphocytic leukemia and currently is under review by the U.S. Food and Drug Administration for the treatment of indolent non-Hodgkin lymphoma that has progressed during or following treatment with rituximab or a rituximab-containing regimen.
- Bendamustine’s unique mechanisms of action may contribute to enhanced efficacy and also may explain its activity in tumors resistant to conventional DNA-damaging agents.
- The administration of bendamustine consists of IV infusion for 30 minutes. Bendamustine is mildly to moderately emetogenic, so patients likely will require premedication with an antiemetic agent. Infusion reactions have occurred.

Pharmacokinetic Profile

Following IV administration, the bendamustine serum concentration declines rapidly (from peak concentration) in a biexponential manner ($t_{1/2a} \approx 17$ minutes and $t_{1/2b} \approx 42$ minutes) (Owen et al.). Bendamustine is highly protein bound (> 95%), primarily to serum albumin; however, protein binding is not altered by low serum albumin, increased age (> 70 years), or advanced tumor burden (Hasse, Priess, & Sohr, 1990). Bendamustine is hydrolyzed to active and inactive metabolites that are eliminated through the bile and the urine (Teichert et al., 2007). Data from patients with NHL suggest that age, gender, mild to moderate renal dysfunction, and mild hepatomegaly (Chiorazzi, Rai, & Ferrarini, 2005). The median age at diagnosis is 70 years, an age at which patients may have significant comorbid conditions. This fact underscores the need for well-tolerated treatments. The management of CLL is based on the stage and aggressiveness of the disease.

Clinical Activity in Hematologic Malignancies

In 2008, hematologic malignancies are estimated to account for 10% of all new cancer cases and deaths in the United States (Jemal et al., 2008). Of those, 48% are because of NHL, followed by MM (14%) and CLL (11%). Currently, no curative therapies for many types of hematologic malignancies are available. A variety of prognostic factors, including cytogenetics, age, performance status, disease stage, and histology, have been identified for hematologic malignancies and are important in treatment selection (Cheson, 2004; Hallek, 2005). Despite many improvements in diagnosis and treatment, a significant need for life-prolonging and well-tolerated treatment remains; this need is expected to grow with the increase in the aging population.

Chronic Lymphocytic Leukemia

CLL is the most common form of leukemia in the United States, with 15,110 new diagnoses and 4,390 related deaths expected in 2008 (Jemal et al., 2008). CLL is a heterogeneous disease characterized by accumulation and proliferation of mature, dysfunctional lymphocytes, leading to bone marrow failure (neutropenia, thrombocytopenia, and anemia), infection, and organ metastases (lymphadenopathy, splenomegaly, hepatomegaly) (Chiorazzi, Rai, & Ferrarini, 2005). The median age at diagnosis is 70 years, an age at which patients may have clinically significant comorbid conditions. This fact underscores the need for well-tolerated treatments. The management of CLL is based on the stage and aggressiveness of the disease.

Preclinical Activity

In vitro studies have demonstrated the apoptotic activity of single-agent bendamustine in hematologic and solid tumor cell lines (Konstantinov, Kostovski, Topashka-Archeva, Genova, & Berger, 2002; Leoni et al., 2004; Strumberg et al., 1996). Importantly, synergistic effects have been documented in B-CLL lymphocytes exposed to the combination of bendamustine and fludarabine (Schwanen et al., 2002), in NHL cells treated with bendamustine and rituximab (Kanekal, Crain, & Eliott, 2004; Rummel, Chow, Hoelzer, Mitrou, & Weidmann, 2002), and in cells from patients with acute myeloid leukemia exposed to the combination of bendamustine and cytarabine (Staib, Schinkothe, & Dimski, 2007). Although in vitro studies in NHL cell lines involving bendamustine and anthracyclines show antagonistic effects on apoptosis (Chow et al., 2001), bendamustine combination therapy with mitoxantrone in advanced CLL has yielded an overall response rate (ORR) of 86% (Koppler, Heymanns, Pandorf, & Weide, 2004). Thus, further clinical investigation of bendamustine’s activity in combination with other chemotherapeutic agents, as well as its utility in a variety of tumor types, is warranted; these studies currently are ongoing.

Clinical Activity

The administration of bendamustine consists of IV infusion for 30 minutes. Bendamustine is mildly to moderately emetogenic, so patients likely will require premedication with an antiemetic agent. Infusion reactions have occurred.

Figure 1. Structure of Bendamustine Hydrochloride

Note. Based on information from Cephalon, Inc., 2008.
Clinical Trials of Bendamustine Therapy for Chronic Lymphocytic Leukemia

Several European trials have demonstrated the activity of single-agent bendamustine in patients with relapsed or refractory CLL (Avardo et al., 2002; Bergmann et al., 2005; Kath, Blumenstengel, Frické, & Hoffken, 2001; Knauf et al., 2007; Lissitchkov, Arnaudov, Peytchev, & Merkle, 2006). Data from selected trials are summarized in Table 1. The observed response rates and preliminary survival data are encouraging in this older adult, pretreated population with disease resistant to alkylators or purine analogs. A large phase III trial comparing bendamustine and chlorambucil in 305 patients with untreated CLL demonstrated a significant improvement in response; however, no difference in overall survival was observed between treatment groups (Knauf et al.).

Non-Hodgkin Lymphoma

NHL is the most common hematologic cancer, ranking as the fifth most common cancer among men and women in the United States (Jemal et al., 2008). An estimated 66,120 new cases and 19,160 deaths are expected in 2008. The prognosis and treatment for NHL are variable and generally based on disease histology, clinical presentation, and presence of adverse risk factors. NHL has more than 40 subtypes, including B-cell and T-cell neoplasms, which broadly are classified into histologies with an aggressive clinical course and those with a more indolent course. Common aggressive histologies include diffuse large B-cell, mantle cell, lymphoblastic, and Burkitt lymphoma. Common indolent types of NHL encompass B-cell follicular lymphoma, marginal zone lymphoma, and small lymphocytic lymphoma. Aggressive disease may present with fever, night sweats, weight loss, organomegaly, and lymphadenopathy, whereas indolent lymphomas commonly present with slowly progressive and typically painless peripheral lymphadenopathy (Ansell & Armitage, 2005). Front-line treatment options include cyclophosphamide, doxorubicin, vincristine, and prednisone (CHOP); cyclophosphamide, vincristine, and prednisone either alone or combined with rituximab; or fludarabine-based chemotherapy regimens (National Comprehensive Cancer Network, 2008a). Radiation as well as bone marrow and stem cell transplantation are additional therapeutic interventions.

Because of the chronic, relapsing nature of indolent NHL, most patients will receive multiple rounds of various therapeutic combinations and ultimately become refractory to chemotherapy or rituximab, thus requiring salvage therapy. In those patients, the goal of treatment is to prolong remission with manageable toxicity. Currently approved therapies for rituximab-refractory, recurrent indolent NHL include radioimmunoconjugates, yttrium-90 ibritumomab tiuxetan, and I-tositumomab-131 (Friedberg, 2004). Despite impressive response rates, the therapies have not yet demonstrated a survival advantage, and their clinical adoption has been slow because of limited patient access to radiologic imaging technology-equipped facilities and concerns over prolonged immune suppression. Optimal use of those agents during the course of clinical disease remains unclear (Davies, 2007). As a result, better therapies in relapsed or refractory indolent disease are needed.

Clinical Trials of Bendamustine Therapy for Indolent Non-Hodgkin Lymphoma

Several clinical trials have evaluated the efficacy and safety of bendamustine alone (Friedberg et al., 2008; Heider & Niederle, 2001; Kahl et al., 2007; Weidmann et al., 2002) or in combination with immunotherapy (e.g., rituximab) and/or chemotherapy (Herold et al., 2006) in moderately to heavily pretreated patients with relapsed or refractory NHL. Efficacy end points from selected trials are summarized in Table 2. A phase III trial in 273 patients with newly diagnosed indolent or mantle cell

<table>
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<th>STUdy</th>
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<th>TREATMENT</th>
<th>MEDIAN OVERALL SURVIVAL (MONTHS)</th>
<th>MEDIAN PFS or TTP (MONTHS)</th>
<th>OVERALL RESPONSE RATE (%)</th>
<th>COMPLETE RESPONSE (%)</th>
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<tr>
<td>Bergmann et al., 2005</td>
<td>10</td>
<td>100 mg/m² B IV on days 1 and 2 every 3–4 weeks</td>
<td>45.6</td>
<td>Not reported</td>
<td>60</td>
<td>20</td>
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<tr>
<td>Lissitchkov et al., 2006</td>
<td>11</td>
<td>100 mg/m² B IV on days 1 and 2 every 3 weeks</td>
<td>Not reported</td>
<td>Not reported</td>
<td>82</td>
<td>36</td>
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<td>Knauf et al., 2007</td>
<td>264</td>
<td>100 mg/m² B IV on days 1 and 2 versus 0.8 mg/kg C on days 1 and 15 every 28 days</td>
<td>Not reported</td>
<td>B 21 versus C 9*</td>
<td>B 68 versus C 39</td>
<td>B 30 versus C 2*</td>
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*p < 0.0001
B—bendamustine; C—chlorambucil; PFS—progression-free survival; TTP—time to progression
lymphoma has demonstrated that treatment with bendamustine plus rituximab was as effective as the combination of CHOP plus rituximab but was associated with a lower incidence of leukopenia, infection, and alopecia (Rummel et al., 2007).

**Multiple Myeloma**

MM is a chronic malignancy of plasma cells within the bone marrow, which leads to lytic bone lesions, bone marrow failure, renal insufficiency, and infectious complications (Kyle et al., 2003). MM predominantly affects older adults; 75% of patients are older than 70 years of age (National Comprehensive Cancer Network, 2008b). An estimated 19,920 patients will be diagnosed with and 10,690 will die from MM in 2008 (Jemal et al., 2008). MM is incurable in most patients and relapse is common. Relapsing disease presents significant treatment challenges because of increased drug resistance and a more aggressive clinical course. Selection of induction therapy is based partly on patient eligibility for stem cell transplantation, but several options are available, including melphalan and prednisone with or without thalidomide or bortezomib; dexamethasone; thalidomide and dexamethasone; lenalidomide or bortezomib; dexamethasone; thalidomide and dexamethasone with or without doxorubicin (National Comprehensive Cancer Network, 2008b). Although these approaches have improved overall survival and quality of life, they have not produced a curative benefit; thus, a need remains for treatment strategies associated with durable response and low toxicity.

**Clinical Trials of Bendamustine Therapy for Multiple Myeloma**

Various clinical trials have demonstrated the activity of bendamustine, alone or in combination with prednisone, in patients with MM (Bremer, 2002; Knop et al., 2005; Ponisch et al., 2006). In a phase III trial comparing melphalan and prednisone versus bendamustine plus prednisone (BP) in patients newly diagnosed with MM, BP was associated with a more rapid achievement of best response (6.8 versus 8.7 cycles), a higher complete response rate (32% versus 13%), a significantly longer remission duration (18 versus 12 months) for patients achieving a complete or partial remission, and higher quality-of-life scores with less bone pain (p < 0.05 for all) (Ponisch et al.). Additional studies have demonstrated that in heavily pretreated patients with relapsed MM, bendamustine produced an ORR exceeding 50% (Bremer), notably in patients who had relapsed following high-dose chemotherapy and stem cell transplantation.

**Solid Tumors**

The efficacy and safety of bendamustine have been evaluated in a variety of solid tumors, including metastatic breast cancer (Eichbaum et al., 2007; Hoffken et al., 1998; von Minckwitz et al., 2005), small cell lung cancer (Schmittel et al., 2007), and head and neck cancer (Rahn et al., 2001; Schilcher, Zeller, Haase, & Rahn, 2001). Those studies support the continued exploration of bendamustine alone and in combination with other therapeutic modalities in patients with advanced solid tumors.

**Dosage and Administration**

The recommended dose of bendamustine is 100 mg/m², infused over 30 minutes, on days 1 and 2 of a 28-day cycle, for a maximum of six cycles (Cephalon, Inc., 2008). Bendamustine is supplied as a lyophilized powder in single-use vials containing 100 mg. Prior to administration, bendamustine is dissolved in sterile water for injection and then diluted in 500 ml of 0.9% sodium chloride. Bendamustine is stable in conventional polyvinylchloride IV bags and infusion sets; once reconstituted, bendamustine is stable for three hours at room temperature or 24 hours when stored refrigerated. Infusion bags do not require protection from light.

Bendamustine should not be combined with other agents or solutions given that compatibility studies have not been performed (Cephalon, Inc., 2008). An in-line filter is not required for administration. Bendamustine is not considered to be a vesicant when diluted and administered as recommended. If bendamustine extravasates during infusion, it may cause irritation to affected tissues.
tissues. Dosage adjustments may be required for prolonged myelosuppression. The effects of renal or hepatic impairment on the disposition and elimination of bendamustine have not yet been established. Caution should be used when treating patients with mild renal dysfunction, and bendamustine should not be used in patients with chromium chloride less than 40 ml per minute. Infusion reactions have occurred.

Adverse Events

An important role of the nurse is to identify, prevent, and treat adverse events related to cancer therapy (see Figure 2). Because chemotherapy-induced toxicities can result in dose delays and reduction and impact quality of life, supportive care measures are critical. An important component of nursing care is to educate patients about the signs and symptoms of chemotherapy-induced toxicity and to report such symptoms. The Oncology Nursing Society (ONS) has published a series of general recommendations, available as ONS Putting Evidence Into Practice® reference cards for the prevention of chemotherapy-induced infection, oral mucositis, and nausea and vomiting. The interventions recommended in those resources provide useful guidelines for nurses caring for patients receiving bendamustine-based regimens (available at www.ons.org/outcomes).

Associated adverse effects are those typically observed with cytotoxic agents, including myelosuppression, gastrointestinal complaints (nausea, vomiting, and constipation), and fatigue. Notably, alopecia and mucositis are infrequent when bendamustine is administered as a single agent. The following sections will discuss the incidence and characteristics of specific adverse events reported to occur during bendamustine treatment and provide recommendations for nursing management. Clinical trials in the United States typically use the National Cancer Institute’s (2008) Common Terminology Criteria for Adverse Events grading scale to objectively describe the severity of an observed side effect. This system defines severity as mild (grade 1), moderate (grade 2), severe (grade 3), life-threatening or disabling (grade 4), or fatal (grade 5). Table 3 presents criteria for the assessment of severity for hematologic adverse effects.

Infusion Reactions

Infusion-related hypersensitivity reactions, primarily cutaneous in nature and relatively uncommon, have occurred in clinical trials with bendamustine. Such allergic-type reactions, which occur during or shortly after the completion of the infusion, may be associated with mild to moderate fever, chills, dyspnea, tachycardia, cyanosis, rash, and hypotension and have been managed successfully with corticosteroid and antihistamine treatments (Kath et al., 2001). Although uncommon, severe anaphylactoid reactions have been reported on day 1 of the second and third cycles of treatment (Friedberg et al., 2008). In a phase II trial in the United States in patients with relapsed NHL, three patients (4%) required discontinuation of bendamustine because of infusion reactions and the remaining four affected patients were able to continue treatment with premedication (Friedberg et al.). During bendamustine infusion, patients should be monitored closely for signs and symptoms of hypersensitivity.

Myelosuppression

Reversible suppression of bone marrow function, including leukopenia, neutropenia, thrombocytopenia, anemia, and lymphocytopenia, has been reported in bendamustine-treated patients (Friedberg et al., 2008; Robinson et al., 2008). Current clinical experience indicates that, in general, the decrease in leukocytes (specifically neutrophils and lymphocytes) is more pronounced than the decline in platelets and hemoglobin. Both leukocytes and platelets often reach nadir at 14–20 days, with bone marrow recovery typically occurring within three to five weeks. Patients should be counseled regarding this anticipated effect on blood cell counts as well as the signs and symptoms of infection. The bone marrow is expected to recover by the start of the next cycle; however, in the setting of a grade 4 neutropenia (absolute neutrophil count [ANC] < 500) or thrombocytopenia (< 75,000), recommendations suggest that the next cycle of treatment be delayed until the ANC and platelet counts reach 1,000 and 75,000, respectively. At that time, the bendamustine dose may be reduced at the discretion of the treating physician. Growth factors and blood product replacement may be administered according to supportive care guidelines. In the phase II single-agent bendamustine study in patients with relapsed or refractory NHL, red blood cell and granulocyte growth factors were administered to 37% and 36% of patients, respectively. Blood product replacement was required in 30% of patients during the trial (Friedberg et al.). Heavily pretreated or severely immunocompromised patients should be monitored closely and may require prophylactic antibiotic therapy.

Gastrointestinal Complaints

The most common nonhematologic side effects associated with bendamustine treatment are mild to moderate nausea and vomiting. Prophylactic antiemetic agents (e.g., dexamethasone, ondansetron, prochlorperazine) may be administered 15–30 minutes before each bendamustine infusion. Delayed nausea

Table 2. Highlights of Nursing Management of Adverse Events

- Myelosuppression associated with bendamustine is generally mild to moderate (grade 1 or 2). Dose modification or delay is recommended in the event of greater than or equal to grade 3 or 4 hematologic toxicity, respectively. Patients and families should be educated about the importance of reporting signs and symptoms of infection.
- Because of the anticipated discomfort associated with nausea and vomiting, antiemetic premedication should be considered before administration of bendamustine.
- Although relatively uncommon, infusion reactions have been observed, typically during the second and third cycles of bendamustine treatment. Patients should be asked about the development of fever, chills, rash, or back pain so that premedication can be considered for future cycles.
- Patients with a high risk for the development of tumor lysis syndrome should receive adequate hydration, allopurinol, and careful monitoring of serum chemistries.
and vomiting have not been reported. Other gastrointestinal-related side effects have included constipation, diarrhea, and loss of appetite. In the phase III trial, events described as mucosal inflammation or stomatitis were reported as mild to moderate (grade 1 or 2) in 21% patients (Kahl et al., 2007).

Tumor Lysis Syndrome

Patients with hematologic malignancies may have an increased risk for the development of tumor lysis syndrome (TLS), a metabolic emergency resulting from the breakdown of tumor cells and the release of their intracellular contents. Based on the anticipated risk for TLS (e.g., tumor burden, serum uric acid, renal function), patients may be given additional IV fluids and oral allopurinol before and during bendamustine treatment. Healthcare providers should monitor serum electrolytes (particularly potassium and phosphorus), serum uric acid, and renal function in patients who are considered to be at risk for developing TLS so that the appropriate treatment can be initiated promptly.

Secondary Malignancies

Like other alkylators, bendamustine may be associated with a risk of treatment-related secondary malignancies (Friedberg et al., 2008; Herold et al., 2006). In the U.S. phase II single-agent trial in patients with indolent lymphoma, secondary malignancies developed in three patients, all of whom eventually died. Two patients developed myelodysplastic syndrome, and one developed chronic myelomonocytic leukemia (Friedberg et al.). Among 242 patients with indolent NHL treated with bendamustine in U.S. trials, the overall incidence of secondary malignancies was 2% (Friedberg et al.; Kahl et al., 2007; Robinson et al., 2008). Bendamustine’s contribution to the development of secondary malignancies is unclear, as the affected patients had received multiple prior therapies, including alkylators, purine analogs, and radioimmunotherapy.

Other

Other adverse effects reported in more than 20% of patients in U.S. trials are fatigue, headache, and cough. Alopecia is uncommon. Bendamustine is in pregnancy category D and can cause fetal harm when administered to a pregnant woman (Cephalon, Inc., 2008).

Key Nursing Management Issues

Awareness of treatment-related toxicities will help nurses provide anticipatory care as well as supportive care to facilitate optimal patient outcomes. Oncology nurses must be knowledgeable about potential bendamustine-related side effects to safely administer the drug and provide thorough patient education to promote safety and compliance. Patient education must include review of commonly expected side effects as well as uncommon, but potentially significant, effects. Nurses should inform patients that mild to moderate neutropenia, anemia, and thrombocytopenia are likely and could result in infection, fatigue, or bleeding, respectively. Patients also should be aware of the potential for nausea, and an antiemetic treatment plan should be established. The management of fatigue also should be discussed. Careful monitoring for fever, chills, rash, or back pain during the infusion is imperative, along with instructions for the patient and family to watch for these signs and symptoms and to contact a healthcare provider if they become severe in the 24-hour period following treatment.

Key clinical nursing assessments throughout the course of treatment include monitoring of laboratory values before and during bendamustine treatment, anticipating the nadir to occur at approximately 14 days after dosing; ensuring that antiemetic therapy is given prior to dosing, as well as evaluating the need for as needed take-home use; watching for signs and symptoms associated with infusion reactions during infusion and asking patients to report symptoms that occur after treatment; and keeping alert to signs and symptoms of TLS, especially in patients at increased risk (i.e., high tumor burden).

Summary

Bendamustine hydrochloride is a new chemotherapeutic agent now available for the treatment of patients with CLL and currently under FDA review for patients with indolent NHL who have progressed during or following treatment with rituximab or a rituximab-containing regimen. Extensive European experience has provided support for its efficacy and safety in patients with hematologic and solid tumor malignancies, and these findings have been confirmed in U.S. trials in...
patients with indolent NHL. Evidence for activity in heavily pretreated patients with relapsed, rituximab-refractory disease suggests that bendamustine offers a new treatment alternative in a patient population with limited treatment options. Myelosuppression is the most serious side effect. Other side effects, including gastrointestinal toxicities, fatigue, and infusion reactions are well known to oncology nurses and can be managed with available treatments.

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