



BUSULFEX®

(busulfan) Injection

Caution: Must be diluted prior to use.

Rx only

WARNING: MYELOSUPPRESSION

BUSULFEX® (busulfan) Injection causes severe and prolonged myelosuppression at the recommended dosage. Hematopoietic progenitor cell transplantation is required to prevent potentially fatal complications of the prolonged myelosuppression. [see *Warnings and Precautions (5.1)*].

1 INDICATIONS AND USAGE

BUSULFEX is indicated for use in combination with cyclophosphamide as a conditioning regimen prior to allogeneic hematopoietic progenitor cell transplantation for chronic myelogenous leukemia.

2 DOSAGE AND ADMINISTRATION

2.1 Initial Dosing Information

- Administer BUSULFEX in combination with cyclophosphamide as a conditioning regimen prior to bone marrow or peripheral blood progenitor cell replacement. For adult patients, the recommended doses (BuCY2 regimen) are:
 - BUSULFEX 0.8 mg/kg (ideal body weight or actual body weight, whichever is lower) intravenously via a central venous catheter as a two-hour infusion every six hours for four consecutive days for a total of 16 doses (Days -7, -6, -5 and -4).
 - Cyclophosphamide 60 mg/kg intravenously as a one-hour infusion on each of two days beginning no sooner than six hours following the 16th dose of BUSULFEX (Days -3 and -2).
 - Administer hematopoietic progenitor cells on Day 0.
- Premedicate patients with anticonvulsants (e.g., benzodiazepines, phenytoin, valproic acid or levetiracetam) to prevent seizures reported with the use of high dose BUSULFEX. Administer anticonvulsants 12 hours prior to BUSULFEX to 24 hours after the last dose of BUSULFEX. [see *Warnings and Precautions (5.2)*]
- Administer antiemetics prior to the first dose of BUSULFEX and continue on a fixed schedule through BUSULFEX administration.
- BUSULFEX clearance is best predicted when the BUSULFEX dose is administered based on adjusted ideal body weight. Dosing BUSULFEX based on actual body weight, ideal body weight or other factors can produce significant differences in BUSULFEX clearance among lean, normal and obese patients.
 - Calculate ideal body weight (IBW) as follows (height in cm, and weight in kg):

Men: $IBW (kg) = 50 + 0.91 \times (\text{height in cm} - 152)$

Women: $IBW (kg) = 45 + 0.91 \times (\text{height in cm} - 152)$

-For obese or severely obese patients, base BUSULFEX dosing on adjusted ideal body weight (AIBW):

$AIBW = IBW + 0.25 \times (\text{actual weight} - IBW)$.

Pediatrics: The effectiveness of BUSULFEX in the treatment of CML has not been specifically studied in pediatric patients. For additional information see Special Populations-Pediatric section

2.2 Preparation and Administration Precautions

DO NOT USE POLYCARBONATE SYRINGES OR POLYCARBONATE FILTER NEEDLES WITH BUSULFEX.

Use an administration set with minimal residual hold-up volume (2-5 cc) for product administration.

BUSULFEX is a cytotoxic drug. Follow applicable special handling and disposal procedures. Skin reactions may occur with accidental exposure. Use gloves when preparing BUSULFEX. If BUSULFEX or diluted BUSULFEX solution contacts the skin or mucosa, wash the skin or mucosa thoroughly with water.

Visually inspect parenteral drug products for particulate matter and discoloration prior to administration whenever the solution and container permit. Do not use if particulate matter is seen in the BUSULFEX vial.

2.3 Preparation for Intravenous Administration

BUSULFEX must be diluted prior to intravenous infusion with either 0.9% Sodium Chloride Injection, USP (normal saline) or 5% Dextrose Injection, USP (D5W). The diluent quantity should be 10 times the volume of BUSULFEX, so that the final concentration of busulfan is approximately 0.5 mg/mL. Calculation of the dose for a 70 kg patient would be performed as follows:

$(70 \text{ kg patient}) \times (0.8 \text{ mg/kg}) \div (6 \text{ mg/mL}) = 9.3 \text{ mL BUSULFEX (56 mg total dose)}$.

To prepare the final solution for infusion, add 9.3 mL of BUSULFEX to 93 mL of diluent (normal saline or D5W) as calculated below:

$(9.3 \text{ mL BUSULFEX}) \times (10) = 93 \text{ mL of either diluent plus the 9.3 mL of BUSULFEX to yield a final concentration of busulfan of } 0.54 \text{ mg/mL } (9.3 \text{ mL} \times 6 \text{ mg/mL} \div 102.3 \text{ mL} = 0.54 \text{ mg/mL})$.

All transfer procedures require strict adherence to aseptic techniques, preferably employing a vertical laminar flow safety hood while wearing gloves and protective clothing.

DO NOT put the BUSULFEX into an intravenous bag or large-volume syringe that does not contain normal saline or D5W. Always add the BUSULFEX to the diluent, not the diluent to the BUSULFEX. Mix thoroughly by inverting several times.

Infusion pumps should be used to administer the diluted BUSULFEX solution. Set the flow rate of the pump to deliver the entire prescribed BUSULFEX dose over two hours. Prior to and following each infusion, flush the indwelling catheter line with approximately 5 mL of 0.9% Sodium Chloride Injection, USP or 5% Dextrose Injection, USP. DO NOT infuse concomitantly with another intravenous solution of unknown compatibility. **WARNING: RAPID INFUSION OF BUSULFEX HAS NOT BEEN TESTED AND IS NOT RECOMMENDED.**

3 DOSAGE FORMS AND STRENGTHS

BUSULFEX Injection is supplied as a clear, colorless, sterile, solution in 10 mL single use vial containing 60 mg of busulfan at a concentration of 6 mg/mL for *intravenous use only*.

4 CONTRAINDICATIONS

BUSULFEX is contraindicated in patients with a history of hypersensitivity to any of its components.

5 WARNINGS AND PRECAUTIONS

The following warnings pertain to different physiologic effects of BUSULFEX in the setting of allogeneic transplantation.

5.1 Myelosuppression

The most frequent serious consequence of treatment with BUSULFEX at the recommended dose and schedule is prolonged myelosuppression, occurring in all patients (100%). Severe granulocytopenia, thrombocytopenia, anemia, or any combination thereof may develop. Hematopoietic progenitor cell transplantation is required to prevent potentially fatal complications of the prolonged myelosuppression. Monitor complete blood counts, including white blood cell differentials, and quantitative platelet counts daily during treatment and until engraftment is demonstrated [*see Patient Counseling Information (17)*]. Absolute neutrophil counts dropped below $0.5 \times 10^9/\text{L}$ at a median of 4 days post-transplant in 100% of patients treated in the BUSULFEX clinical trial. The absolute neutrophil count recovered at a median of 13 days following allogeneic transplantation when prophylactic G-CSF was used in the majority of patients. Thrombocytopenia ($<25,000/\text{mm}^3$ or requiring platelet transfusion) occurred at a median of 5-6 days in 98% of patients. Anemia (hemoglobin $< 8.0 \text{ g/dL}$) occurred in 69% of patients. Use antibiotic therapy and platelet and red blood cell support when medically indicated.

5.2 Seizures

Seizures have been reported in patients receiving high-dose oral busulfan at doses producing plasma drug levels similar to those achieved following the recommended dosage of BUSULFEX. Despite prophylactic therapy with phenytoin, one seizure (1/42 patients) was reported during an autologous transplantation clinical trial of BUSULFEX. This episode occurred during the cyclophosphamide portion of the conditioning regimen, 36 hours after the last BUSULFEX dose. Initiate phenytoin therapy or any other alternative anti-convulsant prophylactic therapy (e.g., benzodiazepines, valproic acid or levetiracetam) prior to BUSULFEX treatment [*see Dosage and Administration (2.1)*]. Use caution when administering the recommended dose of BUSULFEX to patients with a history of a seizure disorder or head trauma or who are receiving other potentially epileptogenic drugs [*see Patient Counseling Information (17)*].

5.3 Hepatic Veno-Occlusive Disease (HVD)

Current literature suggests that high busulfan area under the plasma concentration verses time curve (AUC) values ($>1,500 \mu\text{M} \cdot \text{min}$) may be associated with an increased risk of developing HVD. Patients who have received prior radiation therapy, greater than or equal to three cycles of chemotherapy, or a prior progenitor cell transplant may be at an increased risk of developing HVD with the recommended BUSULFEX dose and regimen. Based on clinical examination and laboratory findings, HVD was diagnosed in 8% (5/61) of patients treated with BUSULFEX in the setting of allogeneic transplantation, was fatal in 2/5 cases (40%), and yielded an overall mortality from HVD in the entire study population of 2/61 (3%). Three of the five patients diagnosed with HVD were retrospectively found to meet the Jones' criteria. The incidence of HVD reported in the literature from the randomized, controlled trials was 7.7%-12% [*see Clinical Studies (14)*]. Monitor serum transaminases, alkaline phosphatase, and bilirubin daily through BMT Day +28 to detect hepatotoxicity, which may herald the onset of HVD [*see Patient Counseling Information (17)*].

5.4 Embryo-fetal Toxicity

BUSULFEX can cause fetal harm when administered to a pregnant woman based on animal data. Busulfan was teratogenic in mice, rats, and rabbits. The solvent, DMA, may also cause fetal harm when administered to a pregnant woman based on findings in animals. Advise pregnant women of the potential risk to a fetus. Advise females and males of reproductive potential to use effective contraception during and after treatment with BUSULFEX [see *Use in Specific Populations* (8.1) and (8.3)].

5.5 Cardiac Tamponade

Cardiac tamponade has been reported in pediatric patients with thalassemia (8/400 or 2% in one series) who received high doses of oral busulfan and cyclophosphamide as the preparatory regimen for hematopoietic progenitor cell transplantation. Six of the eight children died and two were saved by rapid pericardiocentesis. Abdominal pain and vomiting preceded the tamponade in most patients. Monitor for signs and symptoms, promptly evaluate and treat if cardiac tamponade is suspected.

5.6 Bronchopulmonary Dysplasia

Bronchopulmonary dysplasia with pulmonary fibrosis is a rare but serious complication following chronic busulfan therapy. The average onset of symptoms is 4 years after therapy (range 4 months to 10 years).

5.7 Cellular Dysplasia

Busulfan may cause cellular dysplasia in many organs. Cytologic abnormalities characterized by giant, hyperchromatic nuclei have been reported in lymph nodes, pancreas, thyroid, adrenal glands, liver, lungs and bone marrow. This cytologic dysplasia may be severe enough to cause difficulty in the interpretation of exfoliative cytologic examinations of the lungs, bladder, breast and the uterine cervix.

5.8 Infections

Bone marrow suppression often results in opportunistic infection that can be lethal. Patients should be monitored for signs of local or systemic infection or bleeding. Their hematologic status should be evaluated appropriately. Prophylactic or empiric use of anti-infectives (bacterial, fungal, viral) should be considered for the prevention and management of infections during the neutropenic period.

6 ADVERSE REACTIONS

The following adverse reactions are discussed in more detail in other sections of the labeling:

- Myelosuppression [see *Warnings and Precautions* (5.1)]
- Seizures [see *Warnings and Precautions* (5.2)]
- HVD [see *Warnings and Precautions* (5.3)]
- Embryo-fetal Toxicity [see *Warnings and Precautions* (5.4)]
- Cardiac Tamponade [see *Warnings and Precautions* (5.5)]
- Bronchopulmonary Dysplasia [see *Warnings and Precautions* (5.6)]
- Cellular Dysplasia [see *Warnings and Precautions* (5.7)]

6.1 Clinical Trials Experience

Because clinical trials are conducted under widely varying conditions, adverse reaction rates observed in the clinical trials of a drug cannot be directly compared to rates in the clinical trials of another drug and may not reflect the rates observed in practice.

Adverse reaction information is primarily derived from the clinical study (N=61) of BUSULFEX and the data obtained for high-dose oral busulfan conditioning in the setting of randomized, controlled trials identified through a literature review.

In the BUSULFEX (busulfan) Injection allogeneic stem cell transplantation clinical trial, all patients were treated with BUSULFEX 0.8 mg/kg as a two-hour infusion every six hours for 16 doses over four days, combined with cyclophosphamide 60 mg/kg x2 days. Ninety-three percent (93%) of evaluable patients receiving this dose of BUSULFEX maintained an AUC < 1,500 $\mu\text{M}\cdot\text{min}$ for dose 9, which has generally been considered the level that minimizes the risk of HVD.

Table 1 lists the non-hematologic adverse reactions events through BMT Day +28 at a rate $\geq 20\%$ in patients treated with BUSULFEX prior to allogeneic hematopoietic cell transplantation.

Table 1: Summary of the Incidence ($\geq 20\%$) of Non-Hematologic Adverse Reactions through BMT Day +28 in Patients who Received BUSULFEX Prior to Allogeneic Hematopoietic Progenitor Cell Transplantation

Non-Hematological Adverse Reactions¹	Percent Incidence
BODY AS A WHOLE	
Fever	80
Headache	69
Asthenia	51
Chills	46
Pain	44
Edema General	28
Allergic Reaction	26
Chest Pain	26
Inflammation at Injection Site	25
Back Pain	23
CARDIOVASCULAR SYSTEM	
Tachycardia	44
Hypertension	36
Thrombosis	33
Vasodilation	25
DIGESTIVE SYSTEM	
Nausea	98
Stomatitis (Mucositis)	97
Vomiting	95
Anorexia	85
Diarrhea	84
Abdominal Pain	72
Dyspepsia	44
Constipation	38
Dry Mouth	26
Rectal Disorder	25
Abdominal Enlargement	23
METABOLIC AND NUTRITIONAL SYSTEM	
Hypomagnesemia	77
Hyperglycemia	66
Hypokalemia	64
Hypocalcemia	49
Hyperbilirubinemia	49
Edema	36
SGPT Elevation	31
Creatinine Increased	21
NERVOUS SYSTEM	
Insomnia	84
Anxiety	72

Dizziness	30
Depression	23
RESPIRATORY SYSTEM	
Rhinitis	44
Lung Disorder	34
Cough	28
Epistaxis	25
Dyspnea	25
SKIN AND APPENDAGES	
Rash	57
Pruritus	28

¹. Includes all reported adverse reactions regardless of severity (toxicity grades 1-4)

Additional Adverse Reactions by Body System

Hematologic: Prolonged prothrombin time

Gastrointestinal: Esophagitis, ileus, hematemesis, pancreatitis, rectal discomfort

Hepatic: Alkaline phosphatase increases, jaundice, hepatomegaly

Graft-versus-host disease: Graft-versus-host disease. There were 3 deaths (5%) attributed to GVHD.

Edema: Hypervolemia, or documented weight increase

Infection: Infection, pneumonia (fatal in one patient and life-threatening in 3% of patients)

Cardiovascular: Arrhythmia, atrial fibrillation, ventricular extrasystoles, third degree heart block, thrombosis (all episodes were associated with the central venous catheter), hypotension, flushing and hot flashes, cardiomegaly, ECG abnormality, left-sided heart failure, and pericardial effusion

Pulmonary: Hyperventilation, alveolar hemorrhage (fatal in 3%), pharyngitis, hiccup, asthma, atelectasis, pleural effusion, hypoxia, hemoptysis, sinusitis, and interstitial fibrosis (fatal in a single case)

Neurologic: Cerebral hemorrhage, coma, delirium, agitation, encephalopathy, confusion, hallucinations, lethargy, somnolence

Renal: BUN increased, dysuria, oliguria, hematuria, hemorrhagic cystitis

Skin: Alopecia, vesicular rash, maculopapular rash, vesiculo-bullous rash, exfoliative dermatitis, erythema nodosum, acne, skin discoloration

Metabolic: Hypophosphatemia, hyponatremia

Other Events: Injection site pain, myalgia, arthralgia, ear disorder

6.2 Postmarketing Experience

Because these reactions are reported voluntarily from a population of uncertain size, it is not always possible to reliably estimate their frequency or establish a causal relationship to drug exposure. The following adverse reactions (reported as MedRA terms) have been identified during post-approval use of BUSULFEX (busulfan) Injection:

Blood and Lymphatic System Disorders: febrile neutropenia

Gastrointestinal Disorders: tooth hypoplasia

Metabolism and Nutrition Disorders: tumor lysis syndrome

Vascular Disorders: thrombotic microangiopathy (TMA)

Infections and Infestations: severe bacterial, viral (e.g., cytomegalovirus viremia) and fungal infections; and sepsis.

6.3 Oral Busulfan Literature Review

A literature review identified four randomized, controlled trials that evaluated a high-dose oral busulfan-containing conditioning regimen for allogeneic bone marrow transplantation in the setting of CML [*see Clinical Studies (14)*]. The safety outcomes reported in those trials are summarized in Table 2 below for a mixed population of hematological malignancies (AML, CML, and ALL).

Table 2: Summary of safety analyses from the randomized, controlled trials utilizing a high dose oral busulfan-containing conditioning regimen that were identified in a literature review.

Clift CML Chronic Phase					
TRM ¹	VOD ²	GVHD ³	Pulmonary	Hemorrhagic Cystitis	Seizure
Death ≤100d =4.1% (3/73)	No Report	Acute≥Grade 2 =35% Chronic=41% (30/73)	1 death from Idiopathic Interstitial Pneumonitis And 1 death from Pulmonary Fibrosis	No Report	No Report
Devergie CML Chronic Phase					
TRM	VOD	GVHD	Pulmonary	Hemorrhagic Cystitis	Seizure
38%	7.7% (5/65) Deaths=4.6% (3/65)	Acute≥Grade 2 =41% (24/59 at risk)	Interstitial Pneumonitis= 16.9% (11/65)	10.8% (7/65)	No report
Ringden CML, AML, ALL					
TRM	VOD	GVHD	Pulmonary	Hemorrhagic Cystitis	Seizure
28%	12%	Acute≥Grade 2 GVHD=26% Chronic GVHD =45%	Interstitial Pneumonitis =14%	24%	6%
Blume CML, AML, ALL					
TRM	VOD	GVHD	Pulmonary	Hemorrhagic Cystitis	Seizure
No Report	Deaths =4.9%	Acute≥Grade 2 GVHD=22% (13/58 at risk) Chronic GVHD =31%	No Report	No Report	No Report

1. TRM = Transplantation Related Mortality
2. VOD = Veno-Occlusive Disease of the liver
3. GVHD = Graft versus Host Disease

7 DRUG INTERACTIONS

Itraconazole decreases busulfan clearance by up to 25%, and may produce an AUC >1500 $\mu\text{M}\cdot\text{min}$ in some patients. Fluconazole (200 mg) has been used with BUSULFEX.

Phenytoin increases the clearance of busulfan by 15% or more, possibly due to the induction of glutathione-S-transferase. Since the pharmacokinetics of BUSULFEX were studied in patients treated with phenytoin, the clearance of BUSULFEX at the recommended dose may be lower and exposure (AUC) higher in patients not treated with phenytoin.

Because busulfan is eliminated from the body via conjugation with glutathione, use of acetaminophen prior to (<72 hours) or concurrent with BUSULFEX may result in reduced busulfan clearance based upon the known property of acetaminophen to decrease glutathione levels in the blood and tissues.

Metronidazole increases plasma levels of busulfan, which may lead to treatment-related toxicities.

8 USE IN SPECIFIC POPULATIONS

8.1 Pregnancy

Risk Summary

BUSULFEX can cause fetal harm when administered to a pregnant woman based on animal data. Busulfan was teratogenic in mice, rats, and rabbits following administration during organogenesis. The solvent, DMA, may also cause fetal harm when administered to a pregnant woman. In rats, DMA doses of approximately 40% of the daily dose of DMA in the BUSULFEX dose on a mg/m^2 basis given during organogenesis caused significant developmental anomalies [*see Data*]. There are no available human data informing the drug-associated risk. Advise pregnant women of the potential risk to a fetus.

The background risk of major birth defects and miscarriage for the indicated populations are unknown. However, the background risk in the U.S. general population of major birth defects is 2-4% and of miscarriage is 15-20% of clinically recognized pregnancies.

Animal Data

Following administration during organogenesis in animals, busulfan caused malformations and anomalies, including significant alterations in the musculoskeletal system, body weight gain, and size. In pregnant rats, busulfan produced sterility in both male and female offspring due to the absence of germinal cells in the testes and ovaries. The solvent, DMA, administered to rats at doses of 400 $\text{mg}/\text{kg}/\text{day}$ (about 40% of the daily dose of DMA in the BUSULFEX dose on a mg/m^2 basis) during organogenesis caused significant developmental anomalies. The most striking abnormalities included anasarca, cleft palate, vertebral anomalies, rib anomalies, and serious anomalies of the vessels of the heart.

8.2 Lactation

Risk Summary

It is not known whether BUSULFEX is present in human milk. Because many drugs are excreted in human milk and because of the potential for tumorigenicity shown for busulfan in human and animal studies, discontinue breastfeeding during treatment with BUSULFEX.

8.3 Females and Males of Reproductive Potential

Contraception

Females

BUSULFEX can cause fetal harm when administered to a pregnant woman [see *Use in Specific Populations (8.1)*]. Advise females of reproductive potential to use effective contraception during and after treatment with BUSULFEX.

Males

BUSULFEX may damage spermatozoa and testicular tissue, resulting in possible genetic fetal abnormalities. Males with female sexual partners of reproductive potential should use effective contraception during and after treatment with BUSULFEX [see *Nonclinical Toxicology (13.1)*].

Infertility

Females

Ovarian suppression and amenorrhea commonly occur in premenopausal women undergoing chronic, low-dose busulfan therapy for chronic myelogenous leukemia.

Males

Sterility, azoospermia, and testicular atrophy have been reported in male patients.

8.4 Pediatric Use

The effectiveness of BUSULFEX in the treatment of CML has not been specifically studied in pediatric patients. An open-label, uncontrolled study evaluated the pharmacokinetics of BUSULFEX in 24 pediatric patients receiving BUSULFEX as part of a conditioning regimen administered prior to hematopoietic progenitor cell transplantation for a variety of malignant hematologic (N=15) or non-malignant diseases (N=9). Patients ranged in age from 5 months to 16 years (median 3 years). BUSULFEX dosing was targeted to achieve an area under the plasma concentration curve (AUC) of 900-1350 $\mu\text{M}\cdot\text{min}$ with an initial dose of 0.8 mg/kg or 1.0 mg/kg (based on ABW) if the patient was greater than 4 or less than or equal to 4 years, respectively. The dose was adjusted based on plasma concentration after completion of dose 1.

Patients received BUSULFEX doses every six hours as a two-hour infusion over four days for a total of 16 doses, followed by cyclophosphamide 50 mg/kg once daily for four days. After one rest day, hematopoietic progenitor cells were infused. All patients received phenytoin as seizure prophylaxis. The target AUC ($900\text{-}1350\pm 5\%$ $\mu\text{M}\cdot\text{min}$) for BUSULFEX was achieved at dose 1 in 71% (17/24) of patients. Steady state pharmacokinetic testing was performed at dose 9 and 13. BUSULFEX levels were within the target range for 21 of 23 evaluable patients.

All 24 patients experienced neutropenia (absolute neutrophil count $<0.5\times 10^9/\text{L}$) and thrombocytopenia (platelet transfusions or platelet count $<20,000/\text{mm}^3$). Seventy-nine percent (19/24) of patients experienced lymphopenia (absolute lymphocyte count $<0.1\times 10^9$). In 23 patients, the ANC recovered to $>0.5\times 10^9/\text{L}$ (median time to recovery = BMT day +13; range = BMT day +9 to +22). One patient who died on day +20 had not recovered to an ANC $>0.5\times 10^9/\text{L}$.

Four (17%) patients died during the study. Two patients died within 28 days of transplant; one with pneumonia and capillary leak syndrome, and the other with pneumonia and veno-occlusive disease. Two patients died prior to day 100; one due to progressive disease and one due to multi-organ failure.

Adverse reactions were reported in all 24 patients during the study period (BMT day -10 through BMT day +28) or post-study surveillance period (day +29 through +100). These included vomiting (100%), nausea (83%), stomatitis (79%), HVD (21%), graft-versus host disease (GVHD) (25%), and pneumonia (21%).

Based on the results of this 24-patient clinical trial, a suggested dosing regimen of BUSULFEX in pediatric patients is shown in the following dosing nomogram:

BUSULFEX Dosing Nomogram	
Patient's Actual Body Weight (ABW)	BUSULFEX Dosage
≤12 kgs	1.1 (mg/kg)
>12 kgs	0.8 (mg/kg)

Simulations based on a pediatric population pharmacokinetic model indicate that approximately 60% of pediatric patients will achieve a target BUSULFEX exposure (AUC) between 900 to 1350 $\mu\text{M}\cdot\text{min}$ with the first dose of BUSULFEX using this dosing nomogram. Therapeutic drug monitoring and dose adjustment following the first dose of BUSULFEX is recommended.

Dose Adjustment Based on Therapeutic Drug Monitoring

Instructions for measuring the AUC of busulfan at dose 1 (see **Blood Sample Collection for AUC Determination**) and the formula for adjustment of subsequent doses to achieve the desired target AUC (1125 $\mu\text{M}\cdot\text{min}$), are provided below.

$$\text{Adjusted dose (mg)} = \text{Actual Dose (mg)} \times \text{Target AUC } (\mu\text{M}\cdot\text{min}) / \text{Actual AUC } (\mu\text{M}\cdot\text{min})$$

For example, if a patient received a dose of 11 mg busulfan and if the corresponding AUC measured was 800 $\mu\text{M}\cdot\text{min}$, for a target AUC of 1125 $\mu\text{M}\cdot\text{min}$, the target mg dose would be:

$$\text{Mg dose} = 11 \text{ mg} \times 1125 \mu\text{M}\cdot\text{min} / 800 \mu\text{M}\cdot\text{min} = 15.5 \text{ mg}$$

Busulfex dose adjustment may be made using this formula and instructions below.

Blood Sample Collection for AUC Determination

Calculate the AUC ($\mu\text{M}\cdot\text{min}$) based on blood samples collected at the following time points:

For dose 1: 2 hr (end of infusion), 4 hr and 6 hr (immediately prior to the next scheduled BUSULFEX administration). Actual sampling times should be recorded.

For doses other than dose 1: Pre-infusion (baseline), 2 hr (end of infusion), 4 hr and 6 hr (immediately prior to the next scheduled BUSULFEX administration).

AUC calculations based on fewer than the three specified samples may result in inaccurate AUC determinations.

For each scheduled blood sample, collect one to three mL of blood into heparinized (Na or Li heparin) Vacutainer® tubes. The blood samples should be placed on wet ice immediately after collection and should be centrifuged (at 4°C) within one hour. The plasma, harvested into appropriate cryovial storage tubes, is to be frozen immediately at -20°C. All plasma samples are to be sent in a frozen state (i.e., on dry ice) to the assay laboratory for the determination of plasma busulfan concentrations.

Calculation of AUC

BUSULFEX AUC calculations may be made using the following instructions and appropriate standard pharmacokinetic formula:

Dose 1 AUC_{∞} Calculation: $AUC_{\infty} = AUC_{0-6hr} + AUC_{\text{extrapolated}}$, where AUC_{0-6hr} is to be estimated using the linear trapezoidal rule and AUC extrapolated can be computed by taking the ratio of the busulfan concentration at Hour 6 and the terminal elimination rate constant, λ_z . The λ_z must be calculated from the terminal elimination phase of the busulfan concentration vs. time curve. A “0” pre-dose busulfan concentration should be assumed, and used in the calculation of AUC.

If the AUC is assessed subsequent to Dose 1, steady-state AUC_{ss} (AUC_{0-6hr}) is to be estimated from the trough, 2 hr, 4 hr and 6 hr concentrations using the linear trapezoidal rule.

Instructions for Drug Administration and Blood Sample Collection for Therapeutic Drug Monitoring

Use an administration set with minimal residual hold up (priming) volume (1-3 mL) for drug infusion to ensure accurate delivery of the entire prescribed dose and to ensure accurate collection of blood samples for therapeutic drug monitoring and dose adjustment.

Prime the administration set tubing with drug solution to allow accurate documentation of the start time of BUSULFEX infusion. Collect the blood sample from a peripheral IV line to avoid contamination with infusing drug. If the blood sample is taken directly from the existing central venous catheter (CVC), **DO NOT COLLECT THE BLOOD SAMPLE WHILE THE DRUG IS INFUSING** to ensure that the end of infusion sample is not contaminated with any residual drug. At the end of infusion (2 hr), disconnect the administration tubing and flush the CVC line with 5 cc of normal saline prior to the collection of the end of infusion sample from the CVC port. Collect the blood samples from a different port than that used for the BUSULFEX infusion. When recording the BUSULFEX infusion stop time, do not include the time required to flush the indwelling catheter line. Discard the administration tubing at the end of the two-hour infusion [*see Dosage and Administration (2.3)*].

8.5 Geriatric Use

Five of sixty-one patients treated in the BUSULFEX clinical trial were over the age of 55 (range 57-64). All achieved myeloablation and engraftment.

8.6 Renal Impairment

BUSULFEX has not been studied in patients with renal impairment.

8.7 Hepatic Impairment

BUSULFEX has not been administered to patients with hepatic insufficiency.

Since busulfan is mainly metabolized through the liver, caution should be observed when BUSULFEX is used in patients with pre-existing impairment of liver function, especially in those with severe hepatic impairment [*see Warnings and Precautions (5.3)*].

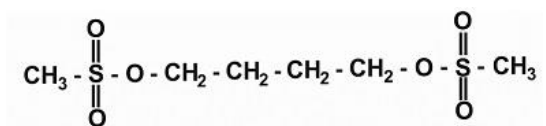
10 OVERDOSAGE

There is no known antidote to BUSULFEX other than hematopoietic progenitor cell transplantation. In the absence of hematopoietic progenitor cell transplantation, the recommended dosage for BUSULFEX would constitute an overdose of

busulfan. The principal toxic effect is profound bone marrow hypoplasia/aplasia and pancytopenia, but the central nervous system, liver, lungs, and gastrointestinal tract may be affected. Monitor hematologic status closely and institute vigorous supportive measures as medically indicated. Survival after a single 140 mg dose of Myleran® Tablets in an 18 kg, 4-year old child has been reported. Inadvertent administration of a greater than normal dose of oral busulfan (2.1 mg/kg; total dose of 23.3 mg/kg) occurred in a 2-year old child prior to a scheduled bone marrow transplant without sequelae. An acute dose of 2.4 g was fatal in a 10-year old boy. There is one report that busulfan is dialyzable, thus dialysis should be considered in the case of overdose.

11 DESCRIPTION

Busulfan is a bifunctional alkylating agent known chemically as 1,4-butanediol, dimethanesulfonate. BUSULFEX® (busulfan) Injection is intended for intravenous administration. It is supplied as a clear, colorless, sterile, solution in 10 mL single use vials. Each vial of BUSULFEX contains 60 mg (6 mg/mL) of busulfan, the active ingredient, a white crystalline powder with a molecular formula of $\text{CH}_3\text{SO}_2\text{O}(\text{CH}_2)_4\text{OSO}_2\text{CH}_3$ and a molecular weight of 246 g/mole. Busulfan has the following chemical structure:



Busulfan is dissolved in N,N-dimethylacetamide (DMA), 3.3 mL and Polyethylene Glycol 400, NF 6.7 mL. The solubility of busulfan in water is 0.1 g/L and the pH of BUSULFEX diluted to approximately 0.5 mg/mL busulfan in 0.9% Sodium Chloride Injection, USP or 5% Dextrose Injection, USP as recommended for infusion reflects the pH of the diluent used and ranges from 3.4 to 3.9.

12 CLINICAL PHARMACOLOGY

12.1 Mechanism of Action

Busulfan is a bifunctional alkylating agent in which two labile methanesulfonate groups are attached to opposite ends of a four-carbon alkyl chain. In aqueous media, busulfan hydrolyzes to release the methanesulfonate groups. This produces reactive carbonium ions that can alkylate DNA. DNA damage is thought to be responsible for much of the cytotoxicity of busulfan.

12.3 Pharmacokinetics

The pharmacokinetics of BUSULFEX were studied in 59 patients participating in a prospective trial of a BUSULFEX-cyclophosphamide preparatory regimen prior to allogeneic hematopoietic progenitor stem cell transplantation. Patients received 0.8 mg/kg BUSULFEX every six hours, for a total of 16 doses over four days. Fifty-five of fifty-nine patients (93%) administered BUSULFEX maintained AUC values below the target value (<1500 $\mu\text{M}\cdot\text{min}$).

Table 3: Steady State Pharmacokinetic Parameters Following Busulfex® (busulfan) Infusion (0.8 mg per kg; N=59)

	Mean	CV (%)	Range
C_{\max} (ng/mL)	1222	18	496-1684
AUC ($\mu\text{M}\cdot\text{min}$)	1167	20	556-1673
CL (mL/r min/kg) ¹	2.52	25	1.49-4.31

¹. Clearance normalized to actual body weight for all patients.

BUSULFEX pharmacokinetics showed consistency between dose 9 and dose 13 as demonstrated by reproducibility of steady state C_{\max} and a low coefficient of variation for this parameter.

Distribution: Busulfan achieves concentrations in the cerebrospinal fluid approximately equal to those in plasma. Busulfan primarily binds to albumin (Mean \pm standard deviation=32.4 \pm 2.2%).

Metabolism: Busulfan is predominantly metabolized by conjugation with glutathione, both spontaneously and by glutathione S-transferase (GST) catalysis. This conjugate undergoes extensive oxidative metabolism in the liver.

Excretion: Following administration of ^{14}C -labeled busulfan to humans, approximately 30% of the radioactivity was excreted into the urine over 48 hours; negligible amounts were recovered in feces.

Specific Populations

Pediatric Patients: In a pharmacokinetic study of BUSULFEX in 24 pediatric patients, the population pharmacokinetic (PPK) estimates of BUSULFEX for clearance (CL) and volume of distribution (V) were determined. For actual body weight, PPK estimates of CL and V were 4.04 L/hr/20 kg (3.37 mL/min/kg; interpatient variability 23%); and 12.8 L/20 kg (0.64 L/kg; interpatient variability 11%).

13 NONCLINICAL TOXICOLOGY

13.1 Carcinogenesis, Mutagenesis, Impairment of Fertility

Busulfan is a mutagen and a clastogen. In *in vitro* tests it caused mutations in *Salmonella typhimurium* and *Drosophila melanogaster*. Chromosomal aberrations induced by busulfan have been reported *in vivo* (rats, mice, hamsters, and humans) and *in vitro* (rodent and human cells). The intravenous administration of busulfan (48 mg/kg given as biweekly doses of 12 mg/kg, or 30% of the total BUSULFEX dose on a mg/m^2 basis) has been shown to increase the incidence of thymic and ovarian tumors in mice.

Busulfan depleted oocytes of female rats and induced sterility in male rats and hamsters. The solvent DMA may also impair fertility. A DMA daily dose of 0.45 g/kg/day given to rats for nine days (equivalent to 44% of the daily dose of DMA contained in the recommended dose of BUSULFEX on a mg/m^2 basis) significantly decreased spermatogenesis in rats. A single subcutaneous dose of 2.2 g/kg (27% of the total DMA dose contained in BUSULFEX on a mg/m^2 basis) four days after insemination terminated pregnancy in 100% of tested hamsters [see *Use in Specific Populations* (8.3)].

14 CLINICAL STUDIES

Documentation of the safety and efficacy of busulfan as a component of a conditioning regimen prior to allogeneic hematopoietic progenitor cell reconstitution is derived from two sources:

- i) analysis of a prospective clinical trial of BUSULFEX that involved 61 patients diagnosed with various hematologic malignancies, and
- ii) the published reports of randomized, controlled trials that employed high-dose oral busulfan as a component of a conditioning regimen for transplantation, which were identified in a literature review of five established commercial databases.

Prospective Clinical Trial of BUSULFEX: The prospective trial was a single-arm, open-label study in 61 patients who received BUSULFEX as part of a conditioning regimen for allogeneic hematopoietic stem cell transplantation. The study included patients with acute leukemia past first remission (first or subsequent relapse), with high-risk first remission, or with induction failure; chronic myelogenous leukemia (CML) in chronic phase, accelerated phase, or blast crisis; primary refractory or resistant relapsed Hodgkin's disease or non-Hodgkin's lymphoma; and myelodysplastic syndrome. Forty-eight percent of patients (29/61) were heavily pretreated, defined as having at least one of the following: prior radiation,

greater than or equal to 3 prior chemotherapeutic regimens, or prior hematopoietic stem cell transplant. Seventy-five percent of patients (46/61) were transplanted with active disease.

Patients received 16 BUSULFEX doses of 0.8 mg/kg every 6 hours as a two-hour infusion for 4 days, followed by cyclophosphamide 60 mg/kg once per day for two days (BuCy2 regimen). All patients received 100% of their scheduled BUSULFEX regimen. No dose adjustments were made. After one rest day, allogeneic hematopoietic progenitor cells were infused. The efficacy parameters in this study were myeloablation (defined as one or more of the following: absolute neutrophil count [ANC] $< 0.5 \times 10^9/L$, absolute lymphocyte count [ALC] $< 0.1 \times 10^9/L$, thrombocytopenia defined as a platelet count $< 20,000/mm^3$ or a platelet transfusion requirement) and engraftment (ANC $\geq 0.5 \times 10^9/L$).

All patients (61/61) experienced myeloablation. The median time to neutropenia was 4 days. All evaluable patients (60/60) engrafted at a median of 13 days post-transplant (range 9 to 29 days); one patient was considered non-evaluable because he died of a fungal pneumonia 20 days after BMT and before engraftment occurred. All but 13 of the patients were treated with prophylactic G-CSF. Evidence of donor cell engraftment and chimerism was documented in all patients who had a chromosomal sex marker or leukemic marker (43/43), and no patient with chimeric evidence of allogeneic engraftment suffered a later loss of the allogeneic graft. There were no reports of graft failure in the overall study population. The median number of platelet transfusions per patient was 6, and the median number of red blood cell transfusions per patient was 4.

Twenty-three patients (38%) relapsed at a median of 183 days post-transplant (range 36 to 406 days). Sixty-two percent of patients (38/61) were free from disease with a median follow-up of 269 days post-transplant (range 20 to 583 days). Forty-three patients (70%) were alive with a median follow up of 288 days post-transplant (range 51 to 583 days). There were two deaths before BMT Day +28 and six additional patients died by BMT Day +100. Ten patients (16%) died after BMT Day +100, at a median of 199 days post-transplant (range 113 to 275 days).

Oral Busulfan Literature Review: Four publications of randomized, controlled trials that evaluated a high-dose oral busulfan-containing conditioning regimen (busulfan 4 mg/kg/d x4 days + cyclophosphamide 60 mg/kg/d x2 days) for allogeneic transplantation in the setting of CML were identified. Two of the studies (Clift and Devergie) had populations confined to CML in chronic phase that were randomized between conditioning with busulfan/cyclophosphamide (BU/CY) and cyclophosphamide/total body irradiation (CY/TBI). A total of 138 patients were treated with BU/CY in these studies. The populations of the two remaining studies (Ringden and Blume) included patients with CML, acute lymphoblastic leukemia (ALL), and acute myelogenous leukemia (AML). In the Nordic BMT Group study published by Ringden, et al., 57 patients had CML, and of those, 30 were treated with BU/CY. Patients with CML in chronic phase, accelerated phase, and blast crisis were eligible for this study. The participants with CML (34/122 patients) in a SWOG study published by Blume, et al., had disease beyond first chronic phase. Twenty of those CML patients were treated with BU/CY, and the TBI comparator arm utilized etoposide instead of cyclophosphamide.

Table 4 summarizes the efficacy analyses reported from these 4 studies.

Table 4: Summary of efficacy analyses from the randomized, controlled trials utilizing a high dose oral busulfan-containing conditioning regimen identified in a literature review.

Clift, 1994							
CML Chronic Phase;							
3 year Overall Survival		3 year DFS		Relapse		Time to Engraftment	
Survival		(p=0.43)				(ANC ≥ 500)	
BU/CY	CY/TBI	BU/CY	CY/TBI	BU/CY	CY/TBI	BU/CY	CY/TBI
80%	80%	71%	68%	13%	13%	22.6 days	22.3 days
Devergie, 1995							
CML Chronic Phase;							
5 year Overall Survival		5 year DFS (p=0.75)		Relapse (Relative Risk analysis		Time to Engraftment	
(p=0.5)				BU/CY:CY/TBI)		(ANC ≥ to 500)	
				(p=0.04)			
BU/CY	CY/TBI	BU/CY	CY/TBI	BU/CY	CY/TBI	BU/CY	CY/TBI
60.6%	65.8%	59.1%	51.0%	4.10		None	None
±11.7%	±12.5%	±11.8%	±14%	(95%CI =1.00-20.28)		Given	Given
Ringden, 1994							
CML, AML, ALL;							
3 year Overall Survival		3 year Relapse Free Survival		Relapse		Time to Engraftment	
(p<0.03)		(p=0.065)		(p=0.9)		(ANC > 500)	
BU/CY	CY/TBI	BU/CY	CY/TBI	BU/CY	CY/TBI	BU/CY	CY/TBI
62%	76%	56%	67%	22%	26%	20 days	20 days
Blume, 1993 ¹							
CML, AML, ALL; Relative Risk Analysis BU/CY: Etoposide/TBI							
RR of Mortality		DFS		RR of Relapse		Time to Engraftment	
				(Relative Risk analysis			

				BU/CY:Eto/TBI)			
BU/CY	Eto/TBI	BU/CY	Eto/TBI	BU/CY	Eto/TBI	BU/CY	Eto/TBI
0.97 (95% CI=0.64-1.48)		Not Given		1.02 (95% CI=0.56-1.86)		Not Given	

¹. Eto = etoposide. TBI was combined with etoposide in the comparator arm of this study.

BU = Busulfan

CY = Cyclophosphamide

TBI = Total Body Irradiation

DFS = Disease Free Survival

ANC = Absolute Neutrophil Count

15 REFERENCES

1. OSHA Hazardous Drugs. OSHA. [Accessed on June 18, 2014 from <http://www.osha.gov/SLTC/hazardousdrugs/index.html>]

16 HOW SUPPLIED/STORAGE AND HANDLING

16.1 How Supplied

BUSULFEX is packaged as a sterile solution in 10 mL single-use clear glass vials each containing 60 mg of busulfan at a concentration of 6 mg/mL for intravenous use.

BUSULFEX is distributed as a unit carton of eight vials.

16.2 Storage and Handling

Unopened vials of BUSULFEX must be stored under refrigerated conditions between 2°C to 8°C (36°F to 46°F).

BUSULFEX diluted in 0.9% Sodium Chloride Injection, USP or 5% Dextrose Injection, USP is stable at room temperature (25°C) for up to 8 hours but the infusion must be completed within that time.

BUSULFEX diluted in 0.9% Sodium Chloride Injection, USP is stable at refrigerated conditions (2°C to 8°C) for up to 12 hours but the infusion must be completed within that time.

BUSULFEX is a cytotoxic drug. Follow applicable special handling and disposal procedures¹.

17 PATIENT COUNSELING INFORMATION

Inform patients of the possibility of developing low blood cell counts and the need for hematopoietic progenitor cell infusion. Instruct patients to immediately report to their healthcare provider if fever develops [*see Warnings and Precautions (5.1)*].

Inform patients of the risks associated with the use of BUSULFEX as well as the plan for regular blood monitoring during therapy. Specifically inform patients of the following: The risk of veno-occlusive liver disease [*see Warnings and Precautions (5.3)*].

Advise females of reproductive potential of the potential risk to a fetus and to inform their healthcare provider with a known or suspected pregnancy [*see Warnings and Precautions (5.4)* and *Use in Specific Populations (8.1)*].

Advise females and males of reproductive potential to use effective contraception during and after treatment with BUSULFEX [*see Use in Specific Populations (8.3)*]

Advise females to discontinue breastfeeding during treatment with BUSULFEX [*see Use in Specific Populations (8.2)*].

Advise females and males of reproductive potential that BUSULFEX may cause temporary or permanent infertility [*see Use in Specific Populations (8.3)*].

The increased risk of malignancy should be explained to the patient.

18. INCOMPATIBILITIES

BUSULFEX must be diluted prior to use with either 0.9% Sodium Chloride Injection, USP (normal saline) or 5% Dextrose Injection, USP. BUSULFEX should not be mixed with other medicinal products.

Distributed and Marketed by:

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