

Summary of Product Characteristics

1 NAME OF THE MEDICINAL PRODUCT

Milrinone 1 mg/ml Solution for Injection/Infusion

2 QUALITATIVE AND QUANTITATIVE COMPOSITION

Each ml of solution contains 1 mg milrinone. Each 10 ml ampoule contains 10 mg milrinone.

For a full list of excipients, see section 6.1.

3 PHARMACEUTICAL FORM

Solution for injection/infusion.

Clear, colourless to pale yellow solution, practically free from particles.

The pH of the solution is 3.2 - 4.0 and the osmolality is 261 – 319 mOsm/Kg.

4 CLINICAL PARTICULARS

4.1 Therapeutic Indications

Milrinone Injection is indicated for the short-term treatment of severe congestive heart failure unresponsive to conventional maintenance therapy, and for the treatment of patients with acute heart failure, including low output states following cardiac surgery.

In paediatric population milrinone is indicated for the short-term treatment (up to 35 hours) of severe congestive heart failure unresponsive to conventional maintenance therapy (glycosides, diuretics, vasodilators and/or angiotensin converting enzyme (ACE) inhibitors), and for the short-term treatment (up to 35 hours) of paediatric patients with acute heart failure, including low output states following cardiac surgery.

4.2 Posology and method of administration

For intravenous administration.

Adults: Milrinone Injection should be given as a loading dose of 50 microgram(s)/kg administered over a period of 10 minutes usually followed by a continuous infusion at a dosage titrated between 0.375 microgram(s)/kg/min and 0.75 microgram(s)/kg/min according to haemodynamic and clinical response, but should not exceed 1.13mg/kg/day total dose. For instructions on dilution of the product before administration and a guide to maintenance infusion delivery rates, see section 6.6.

Solutions of different concentrations may be used according to patient fluid requirements. The duration of therapy should depend upon the patient's response. In congestive cardiac failure, patients have been maintained on the infusion for up to 5 days, although the usual period is 48 to 72 hours. In acute states following cardiac surgery, it is unlikely that treatment need be maintained for more than 12 hours.

Renal Impairment: Dosage adjustment required. Data obtained from patients with severe renal impairment but without heart failure have demonstrated that the presence of renal impairment significantly increases the terminal elimination half-life of milrinone. For patients with clinical evidence of renal impairment, the loading dose is not affected, but the infusion rate should be adjusted according to haemodynamic response. Recommended maintenance infusion rates are provided in section 6.6.

Elderly: Experience so far suggests that no special dosage recommendations are necessary.

Paediatric population:

In published studies selected doses for infants and children were:

- Intravenous loading dose: 50 to 75 microgram(s)/kg administered over 30 to 60 minutes.

- Intravenous continuous infusion: To be initiated on the basis of hemodynamic response and the possible onset of undesirable effects between 0.25 to 0.75 microgram(s)/kg/min for a period up to 35 hours.

In clinical studies on low cardiac output syndrome in infants and children under 6 years of age after corrective surgery for congenital heart disease 75 microgram(s)/kg loading dose over 60 minutes followed by a 0.75 microgram(s)/kg/min infusion for 35 hours significantly reduced the risk of development of low cardiac output syndrome.

Results of pharmacokinetic studies (see section 5.2) have to be taken into consideration.

Renal impairment:

Due to lack of data the use of milrinone is not recommended in paediatric population with renal impairment (for further information please see section 4.4).

Patent ductus arteriosus:

If the use of milrinone is desirable in preterm or term infants at risk of/with patent ductus arteriosus, the therapeutic need must be weighed against potential risks (see section 4.4, 4.8, 5.2, and 5.3).

4.3 Contraindications

- Hypersensitivity to milrinone or any of the excipients
- Severe hypovolaemia.

4.4 Special warnings and precautions for use

The use of inotropic agents such as milrinone during the acute phase of a myocardial infarction may lead to an undesirable increase in myocardial oxygen consumption (MVO₂). Milrinone Injection is not recommended immediately following acute myocardial infarction until safety and efficacy have been established in this situation.

Careful monitoring should be maintained during Milrinone Injection therapy including blood pressure, heart rate, clinical state, electro-cardiogram, fluid balance, electrolytes and renal function (i.e. serum creatinine).

In patients with severe obstructive aortic or pulmonary valvular disease, or hypertrophic subaortic stenosis, Milrinone Injection should not be used in place of surgical relief of the obstruction. In these conditions it is possible that a drug with inotropic / vasodilator properties might aggravate outflow obstruction.

Supraventricular and ventricular arrhythmias have been observed in the high risk population treated with milrinone. In some patients, an increase in ventricular ectopy including non-sustained ventricular tachycardia has been observed which did not affect patient safety or outcome.

The potential for arrhythmia, present in heart failure itself, may be increased by many drugs or a combination of drugs. Patients receiving Milrinone Injection should be closely monitored during infusion and the infusion should be stopped if arrhythmias develop.

As milrinone produces a slight enhancement in A-V node conduction, there is a possibility of an increased ventricular response rate in patients with uncontrolled atrial flutter / fibrillation. Consideration should therefore be given to digitalisation or treatment with other agents to prolong A-V node conduction time prior to starting Milrinone Injection therapy, and to discontinuing the therapy if arrhythmias occur.

Milrinone may induce hypotension as a consequence of its vasodilatory activity; therefore caution should be exercised when Milrinone Injection is administered to patients who are hypotensive prior to treatment. The rate of infusion should be slowed or stopped in patients showing excessive decreases in blood pressure.

If prior vigorous diuretic therapy is suspected of having caused significant decreases in cardiac filling pressure Milrinone Injection should be cautiously administered while monitoring blood pressure, heart rate and clinical symptomatology.

Improvement in cardiac output with resultant diuresis may necessitate a reduction in the dose of diuretic. Potassium loss due to excessive diuresis may necessitate a reduction in the dose of diuretic. Potassium loss due to excessive diuresis may

predispose digitalised patients to arrhythmias. Therefore, hypokalaemia should be corrected by potassium supplementation in advance of, or during, the use of Milrinone Injection.

Decrease in haemoglobin, including anaemia, often takes place in the setting of cardiac failure. Due to the risk of thrombocytopenia or anaemia, careful monitoring of the corresponding laboratory parameters is required in patients with decreased platelet count or decreased haemoglobin.

There is no experience in controlled trials with infusions of milrinone for periods exceeding 48 hours.

Cases of infusion site reaction have been reported with Milrinone Injection (see Section 4.8 Undesirable effects). Consequently, careful monitoring of the infusion site should be maintained so as to avoid possible extravasation.

Use in the elderly: There are no special recommendations for elderly patients. No age-related effects on the incidence of adverse reactions have been observed. Controlled pharmacokinetic studies have not shown changes in the pharmacokinetic profile of milrinone in the elderly.

In patients with severe renal impairment dosage adjustment is required (see section 4.2 Posology and method of administration).

Paediatric population:

The following should be considered in addition to the warnings and precautions described for adults:

In neonates, following open heart surgery during milrinone therapy, monitoring should include heart rate and rhythm, systemic arterial blood pressure via umbilical artery catheter or peripheral catheter, central venous pressure, cardiac index, cardiac output, systemic vascular resistance, pulmonary artery pressure, and atrial pressure. Laboratory values that should be followed are platelet count, serum potassium, liver function, and renal function. Frequency of assessment is determined by baseline values, and it is necessary to evaluate the neonate's response to changes in therapy.

Literature revealed that in paediatric patients with impaired renal function, there were marked impairment of milrinone clearance and clinically significant side effects, but the specific creatinine clearance at which doses must be adjusted in paediatric patients is still not clear, therefore the use of milrinone is not recommended in this population (see section 4.2).

In paediatric patients milrinone should be initiated only if the patient is hemodynamically stable.

Caution should be exercised in neonates with risk factors of intraventricular haemorrhage (i.e. preterm infant, low birth weight) since milrinone may induce thrombocytopenia. In clinical studies in paediatric patients, risk of thrombocytopenia increased significantly with duration of infusion. Clinical data suggest that milrinone-related thrombocytopenia is more common in children than in adults (see section 4.8).

In clinical studies milrinone appeared to slow the closure of the ductus arteriosus in paediatric population. Therefore, if the use of milrinone is desirable in preterm or term infants at risk of/with patent ductus arteriosus, the therapeutic need must be weighed against potential risks (see section 4.2, 4.8, 5.2, and 5.3).

This medicine contains less than 1 mmol sodium (23 mg) per dose, that is to say essentially 'sodium-free'.

4.5 Interaction with other medicinal products and other forms of interactions

Furosemide or bumetanide should not be administered in intravenous lines containing milrinone lactate in order to avoid precipitation.

Milrinone should not be diluted in sodium bicarbonate intravenous infusion.

Whilst there is a theoretical potential interaction with calcium channel blockers, there has been no evidence of a clinically significant interaction to date.

Milrinone has a favourable inotropic effect in fully digitalised patients without causing signs of glycoside toxicity.

Fluid and electrolyte changes, as well as serum creatinine levels should be carefully monitored during treatment with milrinone. Improvement in cardiac output and consequently, diuresis, may require reduction in the dose of a diuretic agent. Potassium

loss due to excessive diuresis may predispose digitalised patients to arrhythmias. Therefore, hypokalaemia should be corrected by potassium supplementation in advance of, or during milrinone use.

4.6 Fertility, pregnancy and lactation

Pregnancy

Although animal studies have not revealed evidence of drug-induced foetal damage or other deleterious effects on reproductive function, the safety of milrinone in human pregnancy has not yet been established. It should be used during pregnancy only if the potential benefit justifies the potential risk to the foetus.

Breast-feeding

There is insufficient information on the excretion of milrinone in human milk. A decision must be made whether to discontinue breast-feeding or to discontinue milrinone therapy taking into account the benefit of breast feeding for a child and the benefit of therapy for the woman.

Fertility

No effects on male and female fertility were observed in 3-generation reproductive studies in rats.

4.7 Effects on ability to drive and use machines

No studies on the effect on the ability to drive and use machines have been performed.

4.8 Undesirable effects

Adverse reactions have been ranked under heading of system-organ class and frequency using the following convention: very common ($\geq 1/10$); common ($\geq 1/100, \leq 1/10$); uncommon ($\geq 1/1,000, \leq 1/100$); rare ($\geq 1/10,000, \leq 1/1,000$); very rare ($\leq 1/10,000$); not known (cannot be estimated from the available data).

Blood and the lymphatic system disorders:

- Uncommon: Thrombocytopenia*
- Not known: reduction of red blood count and/or haemoglobin concentration

*In infants and children, risk of thrombocytopenia increased significantly with duration of infusion. Clinical data suggest that milrinone-related thrombocytopenia is more common in children than in adults (see section 4.4).

Immune system disorders:

- Very rare: Anaphylactic shock

Metabolism and nutrition disorders:

- Uncommon: Hypokalaemia

Nervous system disorders:

- Common: Headaches, usually mild to moderate in severity
- Uncommon: Tremor

Cardiac disorders:

- Common:

- Ventricular ectopic activity
- Non sustained or sustained ventricular Tachycardia (see section 4.4)
- Supraventricular arrhythmias
- Hypotension

- Uncommon:

- Ventricular fibrillation
- Angina/chest pain

- Very rare: Torsades de pointes

The incidence of arrhythmias has not been related to dose or plasma levels of milrinone. These arrhythmias are rarely life threatening. If present, they are often associated with certain underlying factors such as pre-existing arrhythmias, metabolic abnormalities (e.g. hypokalaemia) abnormal digoxin levels and catheter insertion. . Clinical data suggest that milrinone-related arrhythmias are less common in children than in adults.

Respiratory, thoracic and mediastinal disorders:

- Very rare: Bronchospasm

Hepato-biliary disorders:

- Uncommon: Liver function tests abnormal

Skin and subcutaneous tissue disorders:

- Very rare: Skin reactions such as rash

Renal and urinary disorders

- Not known: Renal failure, secondary to a concomitant hypotension

General disorders and administration site conditions:

- Not known: Infusion site reaction

Paediatric population:

Nervous system disorders

Not known: intraventricular haemorrhage (see section 4.4)

Congenital, familial, and genetic disorders

Not known: patent ductus arteriosus*** (see section 4.2, 4.4, 5.2, and 5.3)

***The critical consequences of the patent ductus arteriosus are related to a combination of pulmonary overcirculation with consecutive pulmonary oedema and haemorrhage and of reduced organ perfusion with consecutive intraventricular haemorrhage and necrotizing enterocolitis with possible fatal outcome as described in literature.

Long-term safety data for paediatric population are not yet available.

Reporting of suspected adverse reactions

Reporting suspected adverse reactions after authorisation of the medicinal product is important. It allows continued monitoring of the benefit/risk balance of the medicinal product. Healthcare professionals are asked to report any suspected adverse reactions via HPRA Pharmacovigilance, Website: www.hpra.ie.

4.9 Overdose

Overdose of intravenous milrinone may produce hypotension (because of its vasodilatory effect) and cardiac arrhythmia. If this occurs, Milrinone Injection administration should be reduced or temporarily discontinued until the patient's condition stabilises. No specific antidote is known, but general measures for circulatory support should be taken.

5 PHARMACOLOGICAL PROPERTIES

5.1 Pharmacodynamic properties

Pharmacotherapeutic group: Cardiac therapy; Phosphodiesterase inhibitor, ATC code: C01CE02

Milrinone is a positive inotrope and vasodilator, with little chronotropic activity. It also improves left ventricular diastolic relaxation. It differs in structure and mode of action from the digitalis glycosides, catecholamines or angiotensin converting enzyme inhibitors. It is a selective inhibitor of peak III phosphodiesterase isoenzyme in cardiac and vascular muscle. It produces slight enhancement of A-V node conduction, but no other significant electrophysiological effects.

In clinical studies Milrinone Injection has been shown to produce prompt improvements in the haemodynamic indices of congestive heart failure, including cardiac output, pulmonary capillary wedge pressure and vascular resistance, without clinically significant effect on heart rate or myocardial oxygen consumption.

Haemodynamic improvement during intravenous milrinone therapy is accompanied by clinical symptomatic improvement in congestive cardiac failure, as measured by change in New York Heart Association classification.

Paediatric population:

Literature review identified clinical studies with patients treated for low cardiac output syndrome following cardiac surgery, septic shock or pulmonary hypertension. The usual dosages were a loading dose of 50 to 75 microgram(s)/kg administered over 30 to 60 minutes followed by an intravenous continuous infusion of 0.25 to 0.75 microgram(s)/kg/min for a period up to 35 hours. In these studies, milrinone demonstrated an increase of cardiac output, a decrease in cardiac filling pressure, a decrease in systemic and pulmonary vascular resistance, with minimal changes in heart rate and in myocardial oxygen consumption.

Studies of a longer use of milrinone are not sufficient to recommend an administration of milrinone during a period of more than 35 hours.

Some studies explored the paediatric use of milrinone in patients with nonhyperdynamic septic shock (Barton et al., 1996; Lindsay et al., 1998); the effect of milrinone on postbypass pulmonary hypertension after tetralogy of Fallot repair (Chu et al., 2000); the combined effect of nitric oxide and milrinone on pulmonary circulation after Fontan-type procedure (Cai et al., 2008).

The results of these studies were inconclusive. Therefore, the use of milrinone in these indications cannot be recommended.

5.2 Pharmacokinetic properties

Following intravenous injections of 12.5 to 125 mcg/kg to congestive heart failure patients, Milrinone Injection had a volume of distribution of 0.38 l/kg/hr, a mean terminal elimination half-life of 2.3 hours, and a clearance of 0.13 l/kg/hr.

Following intravenous infusions of 0.2 to 0.7 mcg/kg/min to congestive heart failure patients, the drug had a volume of distribution of about 0.45 l/kg, a mean terminal elimination half-life of 2.4 hours, and a clearance of 0.14 l/kg/hr. These pharmacokinetic parameters were not dose-dependent, and the area under the plasma concentration versus time curve following injection was significantly dose-dependent.

The primary route of excretion of milrinone in man is via the urine. Elimination in normal subjects via the urine is rapid, with approximately 60% recovered within the first two hours following dosing, and approximately 90% recovered within the first eight hours following dosing. The mean renal clearance of milrinone is approximately 0.3 l/min, indicative of active secretion.

Paediatric population:

Milrinone is cleared more rapidly in children than in adults, but infants have significantly lower clearance than children, and preterm infants have even lower clearance. As a consequence of this more rapid clearance compared to adults, steady-state plasma concentrations of milrinone were lower in children than in adults. In paediatric population with normal renal function steady-state milrinone plasma concentrations after 6 to 12 hours continuous infusion of 0.5 to 0.75 microgram(s)/kg/min were about of 100 to 300 ng/ml.

Following intravenous infusion of 0.5 to 0.75 microgram(s)/kg/min to neonates, infants and children after open heart surgery, milrinone has a volume of distribution ranging from 0.35 to 0.9 litres/kg with no significant difference across age groups. Following intravenous infusion of 0.5 microgram(s)/kg/min to very preterm infants to prevent low systemic outflow after birth, milrinone has a volume of distribution of about 0.5 litres/kg.

Several pharmacokinetic studies showed that, in paediatric population, clearance increases with increasing age. Infants have significantly lower clearance than children (3.4 to 3.8 ml/kg/min versus 5.9 to 6.7 ml/kg/min). In neonates milrinone clearance was about 1.64 ml/kg/min and preterm infants have even lower clearance (0.64 ml/kg/min).

Milrinone has a mean terminal half-life of 2 to 4 hours in infants and children and a mean terminal elimination half-life of 10 hours in preterm infants.

It was concluded that the optimal dose of milrinone in paediatric patients in order to obtain plasma levels above the threshold of pharmacodynamic efficacy appeared higher than in adults, but that optimal dose in preterms in order to obtain plasma levels above the threshold of pharmacodynamic efficacy appeared lower than in children.

Patent ductus arteriosus:

Milrinone is cleared by renal excretion and has a volume of distribution that is restricted to extracellular space which suggests that the fluid overload and hemodynamic changes associated with patent ductus arteriosus may have an effect on distribution and excretion of milrinone (see section 4.2, 4.4, 4.8, and 5.3).

5.3 Preclinical safety data

Juvenile animals:

A preclinical study was performed to clarify the ductus-dilating effects of PDE 3 inhibitors in near-term rat pups and their differential effects in near-term and preterm foetal rats. Postnatal ductus arteriosus dilatation by milrinone was studied with three doses (10, 1 and 0.1 mg/kg). The dilating effects of milrinone in the foetal ductus constricted by indomethacin were studied by simultaneous administration of milrinone (10, 1 and 0.1 mg/kg) and indomethacin (10 mg/kg) to the mother rat at D21 (near-term) and D19 (preterm). This in vivo study has shown that milrinone induces dose-dependent dilation of the foetal and the postnatal constricted ductus arteriosus. Dilating effects were more potent with injection immediately after birth than at 1 hour after birth. In addition, study showed that the premature ductus arteriosus is more sensitive to milrinone than the mature ductus arteriosus (see section 4.2, 4.4, 4.8, and 5.2).

6 PHARMACEUTICAL PARTICULARS

6.1 List of excipients

(S)-Lactic Acid
Anhydrous Glucose
Water for Injections
Sodium Hydroxide (for pH adjustment)
Lactic Acid (for pH adjustment)

6.2 Incompatibilities

Furosemide or bumetanide should not be administered in intravenous lines containing Milrinone Injection since precipitation occurs on admixture. Sodium Bicarbonate Intravenous infusion should not be used for dilution.

In the absence of compatibility studies, this medicinal product must not be mixed with other medicinal products.

6.3 Shelf life

3 years for the unopened product.

After dilution: Chemical and physical in-use stability has been demonstrated for 48 hours at 5°C when diluted with 0.45% sodium chloride infusion, 0.9% sodium chloride infusion or 5% glucose infusion.

From a microbiological point of view, the product should be used immediately. If not used immediately, in-use storage times and conditions prior to use are the responsibility of the user and would normally not be longer than 24 hours at 2 to 8°C, unless dilution has taken place in controlled and validated aseptic conditions.

6.4 Special precautions for storage

Store below 25°C. Do not freeze.

For storage conditions of the medical product after dilution, please see section 6.3.

6.5 Nature and contents of container

Milrinone 1mg/ml Solution for Injection/Infusion is presented in 10ml clear, neutral glass (PhEur, Type I) ampoules. The ampoules are packed in a PVC tray and cardboard box in packs of 10.

6.6 Special precautions for disposal and other handling**Instructions for dilution:**

Infusion solutions should be freshly prepared before use. Parenteral drug products should be examined visually and should not be used if particulate matter or discolouration are present.

The following diluents may be used to prepare solutions for infusion:

0.45% sodium chloride infusion

0.9% sodium chloride infusion

5% glucose infusion

A solution containing 200 microgram(s)/ml milrinone should be prepared by taking the contents of a 10 ml ampoule and adding 40 ml of one of the above diluents (400 ml diluent per 100 ml Milrinone Injection).

For single use. Discard any unused solution.

Delivery rates:*Adults:*

The following provides a guide to maintenance infusion delivery rate based upon a solution containing milrinone 200 microgram(s)/ml, prepared as described above.

Milrinone Injection Dose	Infusion Delivery Rate
(microgram(s)/kg/min)	(ml/kg/hr)

0.375	0.11
0.400	0.12
0.500	0.15
0.600	0.18
0.700	0.21
0.750	0.22

Renal impairment:

The following maintenance infusion rates are recommended using the infusion solution described above.

Creatinine Clearance (ml/min/1.73m²)	Milrinone Injection Dose (microgram(s)/kg/min)	Maintenance Infusion Delivery Rate (ml/kg/hr)
5	0.20	0.06
10	0.23	0.07
20	0.28	0.08
30	0.33	0.10
40	0.38	0.11
50	0.43	0.13

The infusion rate should be adjusted according to haemodynamic response. See section 4.2.

7 MARKETING AUTHORISATION HOLDER

Pinewood Laboratories Ltd,
Ballymacarbry
Clonmel
Co. Tipperary
Ireland

8 MARKETING AUTHORISATION NUMBER

PA0281/244/001

9 DATE OF FIRST AUTHORISATION/RENEWAL OF THE AUTHORISATION

Date of first authorisation: 16th September 2016

Date of last renewal: 23rd July 2021

10 DATE OF REVISION OF THE TEXT

June 2022