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# CARNITOR<sup>®</sup> (levocarnitine)

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CARNITOR<sup>®</sup> (levocarnitine) Tablets (330 mg)

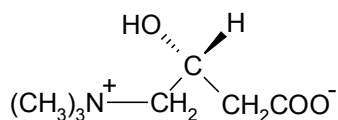
CARNITOR<sup>®</sup> (levocarnitine) Oral Solution (1 g per 10 mL multidose)

For oral use only. **Not for parenteral use.**

## DESCRIPTION

CARNITOR<sup>®</sup> (levocarnitine) is a carrier molecule in the transport of long-chain fatty acids across the inner mitochondrial membrane.

The chemical name of levocarnitine is 3-carboxy-2(*R*)-hydroxy-N,N,N-trimethyl-1-propanaminium, inner salt. Levocarnitine is a white crystalline, hygroscopic powder. It is readily soluble in water, hot alcohol, and insoluble in acetone. The specific rotation of levocarnitine is between -29° and -32°. Its chemical structure is:



Empirical Formula: C<sub>7</sub>H<sub>15</sub>NO<sub>3</sub>

Molecular Weight: 161.20

Each CARNITOR<sup>®</sup> (levocarnitine) Tablet contains 330 mg of levocarnitine and the inactive ingredients magnesium stearate, microcrystalline cellulose and povidone.

Each 118 mL container of CARNITOR<sup>®</sup> (levocarnitine) Oral Solution contains 1 g of levocarnitine/10 mL. Also contains: Artificial Cherry Flavor, D,L-Malic Acid, Purified Water, Sucrose Syrup. Methylparaben NF and Propylparaben NF are added as preservatives. The pH is approximately 5.

## CLINICAL PHARMACOLOGY

CARNITOR<sup>®</sup> (levocarnitine) is a naturally occurring substance required in mammalian energy metabolism. It has been shown to facilitate long-chain fatty acid entry into cellular mitochondria, thereby delivering substrate for oxidation and subsequent energy production. Fatty acids are utilized as an energy substrate in all tissues except the brain. In skeletal and cardiac muscle, fatty acids are the main substrate for energy production.

Primary systemic carnitine deficiency is characterized by low concentrations of levocarnitine in plasma, RBC, and/or tissues. It has not been possible to determine which symptoms are due to carnitine deficiency and which are due to an underlying organic acidemia, as symptoms of both abnormalities may be expected to improve with CARNITOR<sup>®</sup>. The literature reports that carnitine can promote the excretion of excess organic or fatty acids in patients with defects in fatty acid metabolism and/or specific organic acidopathies that bioaccumulate acylCoA esters.<sup>1-6</sup>

Secondary carnitine deficiency can be a consequence of inborn errors of metabolism. CARNITOR<sup>®</sup> may alleviate the metabolic abnormalities of patients with inborn errors that result in accumulation of toxic organic acids. Conditions for which this effect has been demonstrated are: glutaric aciduria II, methyl malonic aciduria, propionic acidemia, and medium chain fatty acylCoA dehydrogenase deficiency.<sup>7,8</sup> Autointoxication occurs in these patients due to the accumulation of acylCoA compounds that disrupt intermediary metabolism. The subsequent hydrolysis of the acylCoA compound to its free acid results in acidosis which can be life-threatening. Levocarnitine clears the acylCoA compound by formation of acylcarnitine, which is quickly excreted. Carnitine deficiency is defined biochemically as abnormally low plasma concentrations of free carnitine, less than 20 µmol/L at one week post term and may be associated with low tissue and/or urine concentrations. Further, this condition may be associated with a plasma concentration ratio of acylcarnitine/levocarnitine greater than 0.4 or abnormally elevated concentrations of acylcarnitine in the urine. In premature infants and newborns, secondary deficiency is defined as plasma levocarnitine concentrations below age-related normal concentrations.

### PHARMACOKINETICS

In a relative bioavailability study in 15 healthy adult male volunteers, CARNITOR<sup>®</sup> Tablets were found to be bio-equivalent to CARNITOR<sup>®</sup> Oral Solution. Following 4 days of dosing with 6 tablets of CARNITOR<sup>®</sup> 330 mg b.i.d. or 2 g of CARNITOR<sup>®</sup> oral solution b.i.d., the maximum plasma concentration ( $C_{max}$ ) was about 80 µmol/L and the time to maximum plasma concentration ( $T_{max}$ ) occurred at 3.3 hours.

The plasma concentration profiles of levocarnitine after a slow 3 minute intravenous bolus dose of 20 mg/kg of CARNITOR<sup>®</sup> were described by a two-compartment model. Following a single i.v. administration, approximately 76% of the levocarnitine dose was excreted in the urine during the 0-24h interval. Using plasma concentrations uncorrected for endogenous levocarnitine, the mean distribution half life was 0.585 hours and the mean apparent terminal elimination half life was 17.4 hours.

The absolute bioavailability of levocarnitine from the two oral formulations of CARNITOR<sup>®</sup>, calculated after correction for circulating endogenous plasma concentrations of levocarnitine, was  $15.1 \pm 5.3\%$  for CARNITOR<sup>®</sup> Tablets and  $15.9 \pm 4.9\%$  for CARNITOR<sup>®</sup> Oral Solution.

Total body clearance of levocarnitine (Dose/AUC including endogenous baseline concentrations) was a mean of 4.00 L/h.

Levocarnitine was not bound to plasma protein or albumin when tested at any concentration or with any species including the human.<sup>9</sup>

### METABOLISM AND EXCRETION

In a pharmacokinetic study where five normal adult male volunteers received an oral dose of [<sup>3</sup>H-methyl]-L-carnitine following 15 days of a high carnitine diet and additional carnitine supplement, 58 to 65% of the administered radioactive dose was recovered in the urine and feces in 5 to 11 days. Maximum concentration of [<sup>3</sup>H-methyl]-L-carnitine in serum occurred from 2.0 to 4.5 hr after drug administration. Major metabolites found were trimethylamine N-oxide, primarily in urine (8% to 49% of the administered dose) and [<sup>3</sup>H]-γ-butyrobetaine, primarily in feces (0.44% to 45% of the administered dose). Urinary excretion of levocarnitine was about 4 to 8% of the dose. Fecal excretion of total carnitine was less than 1% of the administered dose.<sup>10</sup>

After attainment of steady state following 4 days of oral administration of CARNITOR<sup>®</sup> Tablets (1980 mg q12h) or Oral Solution (2000 mg q12h) to 15 healthy male volunteers, the mean urinary excretion of levocarnitine during a single dosing interval (12h) was about 9% of the orally administered dose (uncorrected for endogenous urinary excretion).

## **INDICATIONS AND USAGE**

CARNITOR<sup>®</sup> (levocarnitine) is indicated in the treatment of primary systemic carnitine deficiency. In the reported cases, the clinical presentation consisted of recurrent episodes of Reye-like encephalopathy, hypoketotic hypoglycemia, and/or cardiomyopathy. Associated symptoms included hypotonia, muscle weakness and failure to thrive. A diagnosis of primary carnitine deficiency requires that serum, red cell and/or tissue carnitine levels be low and that the patient does not have a primary defect in fatty acid or organic acid oxidation (see Clinical Pharmacology). In some patients, particularly those presenting with cardiomyopathy, carnitine supplementation rapidly alleviated signs and symptoms. Treatment should include, in addition to carnitine, supportive and other therapy as indicated by the condition of the patient.

CARNITOR<sup>®</sup> (levocarnitine) is also indicated for acute and chronic treatment of patients with an inborn error of metabolism which results in a secondary carnitine deficiency.

## **CONTRAINDICATIONS**

None known.

## **WARNINGS**

None.

## **PRECAUTIONS**

### **General**

CARNITOR<sup>®</sup> (levocarnitine) Oral Solution is for oral/internal use only.

### **Not for parenteral use.**

Gastrointestinal reactions may result from a too rapid consumption of carnitine. CARNITOR<sup>®</sup> (levocarnitine) Oral Solution may be consumed alone, or dissolved in drinks or other liquid foods to reduce taste fatigue. It should be consumed slowly and doses should be spaced evenly throughout the day to maximize tolerance.

The safety and efficacy of oral levocarnitine has not been evaluated in patients with renal insufficiency. Chronic administration of high doses of oral levocarnitine in patients with severely compromised renal function or in ESRD patients on dialysis may result in accumulation of the potentially toxic metabolites, trimethylamine (TMA) and trimethylamine-N-oxide (TMAO), since these metabolites are normally excreted in the urine.

### **Carcinogenesis, mutagenesis, impairment of fertility**

Mutagenicity tests performed in *Salmonella typhimurium*, *Saccharomyces cerevisiae*, and *Schizosaccharomyces pombe* indicate that levocarnitine is not mutagenic. No long-term animal studies have been performed to evaluate the carcinogenic potential of levocarnitine.

## **Pregnancy**

### **Pregnancy Category B.**

Reproductive studies have been performed in rats and rabbits at doses up to 3.8 times the human dose on the basis of surface area and have revealed no evidence of impaired fertility or harm to the fetus due to CARNITOR<sup>®</sup>. There are, however, no adequate and well controlled studies in pregnant women.

Because animal reproduction studies are not always predictive of human response, this drug should be used during pregnancy only if clearly needed.

## **Nursing Mothers**

Levocarnitine supplementation in nursing mothers has not been specifically studied.

Studies in dairy cows indicate that the concentration of levocarnitine in milk is increased following exogenous administration of levocarnitine. In nursing mothers receiving levocarnitine, any risks to the child of excess carnitine intake need to be weighed against the benefits of levocarnitine supplementation to the mother. Consideration may be given to discontinuation of nursing or of levocarnitine treatment.

## **Pediatric Use**

See Dosage and Administration.

## **ADVERSE REACTIONS**

Various mild gastrointestinal complaints have been reported during the long-term administration of oral L- or D,L-carnitine; these include transient nausea and vomiting, abdominal cramps, and diarrhea. Mild myasthenia has been described only in uremic patients receiving D,L-carnitine. Gastrointestinal adverse reactions with CARNITOR<sup>®</sup> (levocarnitine) Oral Solution dissolved in liquids might be avoided by a slow consumption of the solution or by a greater dilution. Decreasing the dosage often diminishes or eliminates drug-related patient body odor or gastrointestinal symptoms when present. Tolerance should be monitored very closely during the first week of administration, and after any dosage increases.

Seizures have been reported to occur in patients with or without pre-existing seizure activity receiving either oral or intravenous levocarnitine. In patients with pre-existing seizure activity, an increase in seizure frequency and/or severity has been reported.

## **OVERDOSAGE**

There have been no reports of toxicity from levocarnitine overdosage. Levocarnitine is easily removed from plasma by dialysis. The intravenous LD<sub>50</sub> of levocarnitine in rats is 5.4 g/kg and the oral LD<sub>50</sub> of levocarnitine in mice is 19.2 g/kg. Large doses of levocarnitine may cause diarrhea.

## **DOSAGE AND ADMINISTRATION**

CARNITOR<sup>®</sup> (levocarnitine) Tablets.

Adults: The recommended oral dosage for adults is 990 mg two or three times a day using the 330 mg tablets, depending on clinical response.

Infants and children: The recommended oral dosage for infants and children is between 50 and 100

mg/kg/day in divided doses, with a maximum of 3 g/day. Dosage should begin at 50 mg/kg/day. The exact dosage will depend on clinical response.

Monitoring should include periodic blood chemistries, vital signs, plasma carnitine concentrations and overall clinical condition.

CARNITOR® (levocarnitine) Oral Solution.  
For oral use only. **Not for parenteral use.**

Adults: The recommended dosage of levocarnitine is 1 to 3 g/day for a 50 kg subject, which is equivalent to 10 to 30 mL/day of CARNITOR® (levocarnitine) Oral Solution. Higher doses should be administered only with caution and only where clinical and biochemical considerations make it seem likely that higher doses will be of benefit. Dosage should start at 1 g/day, (10 mL/day), and be increased slowly while assessing tolerance and therapeutic response. Monitoring should include periodic blood chemistries, vital signs, plasma carnitine concentrations, and overall clinical condition.

Infants and children: The recommended dosage of levocarnitine is 50 to 100 mg/kg/day which is equivalent to 0.5 mL/kg/day CARNITOR® (levocarnitine) Oral Solution. Higher doses should be administered only with caution and only where clinical and biochemical considerations make it seem likely that higher doses will be of benefit. Dosage should start at 50 mg/kg/day, and be increased slowly to a maximum of 3 g/day (30 mL/day) while assessing tolerance and therapeutic response. Monitoring should include periodic blood chemistries, vital signs, plasma carnitine concentrations, and overall clinical condition.

CARNITOR® (levocarnitine) Oral Solution may be consumed alone or dissolved in drink or other liquid food. Doses should be spaced evenly throughout the day (every three or four hours) preferably during or following meals and should be consumed slowly in order to maximize tolerance.

#### **HOW SUPPLIED**

CARNITOR® (levocarnitine) Tablets are supplied as 330 mg tablets embossed with “CARNITOR ST” in individual blisters, packaged in boxes of 90 (NDC 54482-144-07). Store at controlled room temperature (25°C). See USP.

CARNITOR® (levocarnitine) Oral Solution is supplied in 118 mL (4 FL. OZ.) multiple-unit plastic containers. The multiple-unit containers are packaged 24 per case (NDC 54482-145-08). Store at controlled room temperature (25°C). See USP. CARNITOR® (levocarnitine) Oral Solution is manufactured for Sigma-Tau Pharmaceuticals, Inc. by: Alpharma USPD, Inc. Baltimore, MD 21244-2654 and/or Hi-Tech Pharmacal Co., Inc. Amityville, NY 11701.

CARNITOR® (levocarnitine) is also available in the following dosage forms for intravenous injection:

CARNITOR® (levocarnitine) Injection is available in 1 g per 5 mL single dose vials packaged 5 vials per carton (NDC 54482-147-01). CARNITOR® (levocarnitine) Injection 5 mL vial is manufactured for Sigma-Tau Pharmaceuticals, Inc. by Chesapeake Biological Laboratories, Inc. Baltimore, MD 21230-2591.

CARNITOR® (levocarnitine) Injection is also available in 1 g per 5 mL single dose ampoules packaged 5

ampoules per carton (NDC 54482-146-09). Made in Italy.

Rx only.

## REFERENCES

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*PREVIOUS EDITION IS OBSOLETE*  
*Date of Issue: 03/02 OPI-5-E*

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CARNITOR<sup>®</sup> (levocarnitine) Tablets (330 mg)

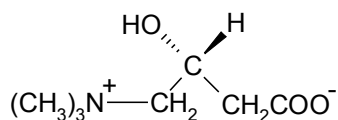
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Secondary carnitine deficiency can be a consequence of inborn errors of metabolism. CARNITOR<sup>®</sup> may alleviate the metabolic abnormalities of patients with inborn errors that result in accumulation of toxic organic acids. Conditions for which this effect has been demonstrated are: glutaric aciduria II, methyl malonic aciduria, propionic acidemia, and medium chain fatty acylCoA dehydrogenase deficiency.<sup>7,8</sup> Autointoxication occurs in these patients due to the accumulation of acylCoA compounds that disrupt intermediary metabolism. The subsequent hydrolysis of the acylCoA compound to its free acid results in acidosis which can be life-threatening. Levocarnitine clears the acylCoA compound by formation of acylcarnitine, which is quickly excreted. Carnitine deficiency is defined biochemically as abnormally low plasma concentrations of free carnitine, less than 20 µmol/L at one week post term and may be associated with low tissue and/or urine concentrations. Further, this condition may be associated with a plasma concentration ratio of acylcarnitine/levocarnitine greater than 0.4 or abnormally elevated concentrations of acylcarnitine in the urine. In premature infants and newborns, secondary deficiency is defined as plasma levocarnitine concentrations below age-related normal concentrations.

### PHARMACOKINETICS

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The plasma concentration profiles of levocarnitine after a slow 3 minute intravenous bolus dose of 20 mg/kg of CARNITOR<sup>®</sup> were described by a two-compartment model. Following a single i.v. administration, approximately 76% of the levocarnitine dose was excreted in the urine during the 0-24h interval. Using plasma concentrations uncorrected for endogenous levocarnitine, the mean distribution half life was 0.585 hours and the mean apparent terminal elimination half life was 17.4 hours.

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### METABOLISM AND EXCRETION

In a pharmacokinetic study where five normal adult male volunteers received an oral dose of [<sup>3</sup>H-methyl]-L-carnitine following 15 days of a high carnitine diet and additional carnitine supplement, 58 to 65% of the administered radioactive dose was recovered in the urine and feces in 5 to 11 days. Maximum concentration of [<sup>3</sup>H-methyl]-L-carnitine in serum occurred from 2.0 to 4.5 hr after drug administration. Major metabolites found were trimethylamine N-oxide, primarily in urine (8% to 49% of the administered dose) and [<sup>3</sup>H]-γ-butyrobetaine, primarily in feces (0.44% to 45% of the administered dose). Urinary excretion of levocarnitine was about 4 to 8% of the dose. Fecal excretion of total carnitine was less than 1% of the administered dose.<sup>10</sup>



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## **INDICATIONS AND USAGE**

CARNITOR<sup>®</sup> (levocarnitine) is indicated in the treatment of primary systemic carnitine deficiency. In the reported cases, the clinical presentation consisted of recurrent episodes of Reye-like encephalopathy, hypoketotic hypoglycemia, and/or cardiomyopathy. Associated symptoms included hypotonia, muscle weakness and failure to thrive. A diagnosis of primary carnitine deficiency requires that serum, red cell and/or tissue carnitine levels be low and that the patient does not have a primary defect in fatty acid or organic acid oxidation (see Clinical Pharmacology). In some patients, particularly those presenting with cardiomyopathy, carnitine supplementation rapidly alleviated signs and symptoms. Treatment should include, in addition to carnitine, supportive and other therapy as indicated by the condition of the patient.

CARNITOR<sup>®</sup> (levocarnitine) is also indicated for acute and chronic treatment of patients with an inborn error of metabolism which results in a secondary carnitine deficiency.

## **CONTRAINDICATIONS**

None known.

## **WARNINGS**

None.

## **PRECAUTIONS**

### **General**

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### **Not for parenteral use.**

Gastrointestinal reactions may result from a too rapid consumption of carnitine. CARNITOR<sup>®</sup> (levocarnitine) Oral Solution may be consumed alone, or dissolved in drinks or other liquid foods to reduce taste fatigue. It should be consumed slowly and doses should be spaced evenly throughout the day to maximize tolerance.

The safety and efficacy of oral levocarnitine has not been evaluated in patients with renal insufficiency. Chronic administration of high doses of oral levocarnitine in patients with severely compromised renal function or in ESRD patients on dialysis may result in accumulation of the potentially toxic metabolites, trimethylamine (TMA) and trimethylamine-N-oxide (TMAO), since these metabolites are normally excreted in the urine.

### **Carcinogenesis, mutagenesis, impairment of fertility**

Mutagenicity tests performed in *Salmonella typhimurium*, *Saccharomyces cerevisiae*, and *Schizosaccharomyces pombe* indicate that levocarnitine is not mutagenic. No long-term animal studies have been performed to evaluate the carcinogenic potential of levocarnitine.

## **Pregnancy**

### **Pregnancy Category B.**

Reproductive studies have been performed in rats and rabbits at doses up to 3.8 times the human dose on the basis of surface area and have revealed no evidence of impaired fertility or harm to the fetus due to CARNITOR<sup>®</sup>. There are, however, no adequate and well controlled studies in pregnant women.

Because animal reproduction studies are not always predictive of human response, this drug should be used during pregnancy only if clearly needed.

## **Nursing Mothers**

Levocarnitine supplementation in nursing mothers has not been specifically studied.

Studies in dairy cows indicate that the concentration of levocarnitine in milk is increased following exogenous administration of levocarnitine. In nursing mothers receiving levocarnitine, any risks to the child of excess carnitine intake need to be weighed against the benefits of levocarnitine supplementation to the mother. Consideration may be given to discontinuation of nursing or of levocarnitine treatment.

## **Pediatric Use**

See Dosage and Administration.

## **ADVERSE REACTIONS**

Various mild gastrointestinal complaints have been reported during the long-term administration of oral L- or D,L-carnitine; these include transient nausea and vomiting, abdominal cramps, and diarrhea. Mild myasthenia has been described only in uremic patients receiving D,L-carnitine. Gastrointestinal adverse reactions with CARNITOR<sup>®</sup> (levocarnitine) Oral Solution dissolved in liquids might be avoided by a slow consumption of the solution or by a greater dilution. Decreasing the dosage often diminishes or eliminates drug-related patient body odor or gastrointestinal symptoms when present. Tolerance should be monitored very closely during the first week of administration, and after any dosage increases.

Seizures have been reported to occur in patients with or without pre-existing seizure activity receiving either oral or intravenous levocarnitine. In patients with pre-existing seizure activity, an increase in seizure frequency and/or severity has been reported.

## **OVERDOSAGE**

There have been no reports of toxicity from levocarnitine overdosage. Levocarnitine is easily removed from plasma by dialysis. The intravenous LD<sub>50</sub> of levocarnitine in rats is 5.4 g/kg and the oral LD<sub>50</sub> of levocarnitine in mice is 19.2 g/kg. Large doses of levocarnitine may cause diarrhea.

## **DOSAGE AND ADMINISTRATION**

CARNITOR<sup>®</sup> (levocarnitine) Tablets.

Adults: The recommended oral dosage for adults is 990 mg two or three times a day using the 330 mg tablets, depending on clinical response.

Infants and children: The recommended oral dosage for infants and children is between 50 and 100

mg/kg/day in divided doses, with a maximum of 3 g/day. Dosage should begin at 50 mg/kg/day. The exact dosage will depend on clinical response.

Monitoring should include periodic blood chemistries, vital signs, plasma carnitine concentrations and overall clinical condition.

CARNITOR® (levocarnitine) Oral Solution.

For oral use only. **Not for parenteral use.**

Adults: The recommended dosage of levocarnitine is 1 to 3 g/day for a 50 kg subject, which is equivalent to 10 to 30 mL/day of CARNITOR® (levocarnitine) Oral Solution. Higher doses should be administered only with caution and only where clinical and biochemical considerations make it seem likely that higher doses will be of benefit. Dosage should start at 1 g/day, (10 mL/day), and be increased slowly while assessing tolerance and therapeutic response. Monitoring should include periodic blood chemistries, vital signs, plasma carnitine concentrations, and overall clinical condition.

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CARNITOR® (levocarnitine) Oral Solution may be consumed alone or dissolved in drink or other liquid food. Doses should be spaced evenly throughout the day (every three or four hours) preferably during or following meals and should be consumed slowly in order to maximize tolerance.

## **HOW SUPPLIED**

CARNITOR® (levocarnitine) Tablets are supplied as 330 mg tablets embossed with “CARNITOR ST” in individual blisters, packaged in boxes of 90 (NDC 54482-144-07). Store at controlled room temperature (25°C). See USP.

CARNITOR® (levocarnitine) Oral Solution is supplied in 118 mL (4 FL. OZ.) multiple-unit plastic containers. The multiple-unit containers are packaged 24 per case (NDC 54482-145-08). Store at controlled room temperature (25°C). See USP. CARNITOR® (levocarnitine) Oral Solution is manufactured for Sigma-Tau Pharmaceuticals, Inc. by: Alpharma USPD, Inc. Baltimore, MD 21244-2654 and/or Hi-Tech Pharmacal Co., Inc. Amityville, NY 11701.

CARNITOR® (levocarnitine) is also available in the following dosage forms for intravenous injection:

CARNITOR® (levocarnitine) Injection is available in 1 g per 5 mL single dose vials packaged 5 vials per carton (NDC 54482-147-01). CARNITOR® (levocarnitine) Injection 5 mL vial is manufactured for Sigma-Tau Pharmaceuticals, Inc. by Chesapeake Biological Laboratories, Inc. Baltimore, MD 21230-2591.


CARNITOR® (levocarnitine) Injection is also available in 1 g per 5 mL single dose ampoules packaged 5

ampoules per carton (NDC 54482-146-09). Made in Italy.

Rx only.

## REFERENCES

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Manufactured by: **Alpharma USPD,**  
**Inc.** Baltimore, MD 21244-2654 for  
Sigma-Tau Pharmaceuticals, Inc.

**PREVIOUS EDITION IS OBSOLETE**  
**Date of Issue: 03/02 OPI(A)-5-E**

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# CARNITOR<sup>®</sup> (levocarnitine)

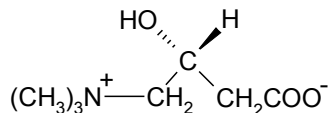
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CARNITOR<sup>®</sup> (levocarnitine) Injection 1 g per 5 mL vial  
FOR INTRAVENOUS USE ONLY.

## DESCRIPTION

CARNITOR<sup>®</sup> (levocarnitine) is a carrier molecule in the transport of long-chain fatty acids across the inner mitochondrial membrane.

The chemical name of levocarnitine is 3-carboxy-2(*R*)-hydroxy-N,N,N-trimethyl-1-propanaminium, inner salt. Levocarnitine is a white crystalline, hygroscopic powder. It is readily soluble in water, hot alcohol, and insoluble in acetone. The specific rotation of levocarnitine is between -29° and -32°. Its chemical structure is:



Empirical Formula: C<sub>7</sub>H<sub>15</sub>NO<sub>3</sub>

Molecular Weight: 161.20

CARNITOR<sup>®</sup> (levocarnitine) Injection is a sterile aqueous solution containing 1 g of levocarnitine per 5 mL vial. The pH is adjusted to 6.0 - 6.5 with hydrochloric acid or sodium hydroxide.

## CLINICAL PHARMACOLOGY

CARNITOR<sup>®</sup> (levocarnitine) is a naturally occurring substance required in mammalian energy metabolism. It has been shown to facilitate long-chain fatty acid entry into cellular mitochondria, thereby delivering substrate for oxidation and subsequent energy production. Fatty acids are utilized as an energy substrate in all tissues except the brain. In skeletal and cardiac muscle, fatty acids are the main substrate for energy production.

Primary systemic carnitine deficiency is characterized by low concentrations of levocarnitine in plasma, RBC, and/or tissues. It has not been possible to determine which symptoms are due to carnitine deficiency and which are due to an underlying organic acidemia, as symptoms of both abnormalities may be expected to improve with CARNITOR<sup>®</sup>. The literature reports that carnitine can promote the excretion of excess organic or fatty acids in patients with defects in fatty acid metabolism and/or specific organic acidopathies that bioaccumulate acylCoA esters.<sup>1-6</sup>

Secondary carnitine deficiency can be a consequence of inborn errors of metabolism or iatrogenic factors such as hemodialysis. CARNITOR<sup>®</sup> may alleviate the metabolic abnormalities of patients with inborn errors that result in accumulation of toxic organic acids. Conditions for which this effect has been demonstrated are: glutaric aciduria II, methyl malonic aciduria, propionic acidemia, and medium chain fatty acylCoA dehydrogenase deficiency.<sup>7,8</sup> Autointoxication occurs in these patients due to the

accumulations of acylCoA compounds that disrupt intermediary metabolism. The subsequent hydrolysis of the acylCoA compound to its free acid results in acidosis which can be life-threatening. Levocarnitine clears the acylCoA compound by formation of acylcarnitine, which is quickly excreted. Carnitine deficiency is defined biochemically as abnormally low plasma concentrations of free carnitine, less than 20  $\mu\text{mol/L}$  at one week post term and may be associated with low tissue and/or urine concentrations. Further, this condition may be associated with a plasma concentration ratio of acylcarnitine/levocarnitine greater than 0.4 or abnormally elevated concentrations of acylcarnitine in the urine. In premature infants and newborns, secondary deficiency is defined as plasma levocarnitine concentrations below age-related normal concentrations.

End Stage Renal Disease (ESRD) patients on maintenance hemodialysis may have low plasma carnitine concentrations and an increased ratio of acylcarnitine/carnitine because of reduced intake of meat and dairy products, reduced renal synthesis and dialytic losses. Certain clinical conditions common in hemodialysis patients such as malaise, muscle weakness, cardiomyopathy and cardiac arrhythmias may be related to abnormal carnitine metabolism.

Pharmacokinetic and clinical studies with CARNITOR<sup>®</sup> have shown that administration of levocarnitine to ESRD patients on hemodialysis results in increased plasma levocarnitine concentrations.

## PHARMACOKINETICS

In a relative bioavailability study in 15 healthy adult male volunteers, CARNITOR<sup>®</sup> Tablets were found to be bio-equivalent to CARNITOR<sup>®</sup> Oral Solution. Following 4 days of dosing with 6 tablets of CARNITOR<sup>®</sup> 330 mg b.i.d. or 2 g of CARNITOR<sup>®</sup> oral solution b.i.d., the maximum plasma concentration ( $C_{\text{max}}$ ) was about 80  $\mu\text{mol/L}$  and the time to maximum plasma concentration ( $T_{\text{max}}$ ) occurred at 3.3 hours.

The plasma concentration profiles of levocarnitine after a slow 3 minute intravenous bolus dose of 20 mg/kg of CARNITOR<sup>®</sup> were described by a two-compartment model. Following a single i.v. administration, approximately 76% of the levocarnitine dose was excreted in the urine during the 0-24h interval. Using plasma concentrations uncorrected for endogenous levocarnitine, the mean distribution half life was 0.585 hours and the mean apparent terminal elimination half life was 17.4 hours.

The absolute bioavailability of levocarnitine from the two oral formulations of CARNITOR<sup>®</sup>, calculated after correction for circulating endogenous plasma concentrations of levocarnitine, was  $15.1 \pm 5.3\%$  for CARNITOR<sup>®</sup> Tablets and  $15.9 \pm 4.9\%$  for CARNITOR<sup>®</sup> Oral Solution.

Total body clearance of levocarnitine (Dose/AUC including endogenous baseline concentrations) was a mean of 4.00 L/h.

Levocarnitine was not bound to plasma protein or albumin when tested at any concentration or with any species including the human.<sup>9</sup>

In a 9-week study, 12 ESRD patients undergoing hemodialysis for at least 6 months received CARNITOR<sup>®</sup> 20 mg/kg three times per week after dialysis. Prior to initiation of CARNITOR<sup>®</sup> therapy, mean plasma levocarnitine concentrations were approximately 20  $\mu\text{mol/L}$  pre-dialysis and 6  $\mu\text{mol/L}$  post-dialysis. The table summarizes the pharmacokinetic data (mean  $\pm$  SD  $\mu\text{mol/L}$ ) after the first dose of CARNITOR<sup>®</sup> and

after 8 weeks of CARNITOR<sup>®</sup> therapy.

N=12	Baseline	Single dose	8 weeks
C <sub>max</sub>	-	1139 ± 240	1190 ± 270
Trough (pre-dialysis, pre-dose)	21.3 ± 7.7	68.4 ± 26.1	190 ± 55

After one week of CARNITOR<sup>®</sup> therapy (3 doses), all patients had trough concentrations between 54 and 180 µmol/L (normal 40-50 µmol/L) and concentrations remained relatively stable or increased over the course of the study.

In a similar study in ESRD patients also receiving 20 mg/kg CARNITOR<sup>®</sup> 3 times per week after hemodialysis, 12- and 24-week mean pre-dialysis (trough) levocarnitine concentrations were 189 (N=25) and 243 (N=23) µmol/L, respectively.

In a dose-ranging study in ESRD patients undergoing hemodialysis, patients received 10, 20, or 40 mg/kg CARNITOR<sup>®</sup> 3 times per week following dialysis (N~30 for each dose group). Mean ± SD trough levocarnitine concentrations (µmol/L) by dose after 12 and 24 weeks of therapy are summarized in the table.

	12 weeks	24 weeks
10 mg/kg	116 ± 69	148 ± 50
20 mg/kg	210 ± 58	240 ± 60
40 mg/kg	371 ± 111	456 ± 162

While the efficacy of CARNITOR<sup>®</sup> to increase carnitine concentrations in patients with ESRD undergoing dialysis has been demonstrated, the effects of supplemental carnitine on the signs and symptoms of carnitine deficiency and on clinical outcomes in this population have not been determined.

## **METABOLISM AND EXCRETION**

In a pharmacokinetic study where five normal adult male volunteers received an oral dose of [<sup>3</sup>H-methyl]-L-carnitine following 15 days of a high carnitine diet and additional carnitine supplement, 58 to 65% of the administered radioactive dose was recovered in the urine and feces in 5 to 11 days. Maximum concentration of [<sup>3</sup>H-methyl]-L-carnitine in serum occurred from 2.0 to 4.5 hr after drug administration. Major metabolites found were trimethylamine N-oxide, primarily in urine (8% to 49% of the administered dose) and [<sup>3</sup>H]-β-butYRObetaine, primarily in feces (0.44% to 45% of the administered dose). Urinary excretion of levocarnitine was about 4 to 8% of the dose. Fecal excretion of total carnitine was less than 1% of the administered dose.<sup>10</sup>

After attainment of steady state following 4 days of oral administration of CARNITOR<sup>®</sup> Tablets (1980 mg q12h) or Oral Solution (2000 mg q12h) to 15 healthy male volunteers, the mean urinary excretion of levocarnitine during a single dosing interval (12h) was about 9% of the orally administered dose (uncorrected for endogenous urinary excretion).

## **INDICATIONS AND USAGE**

For the acute and chronic treatment of patients with an inborn error of metabolism which results in secondary carnitine deficiency.

For the prevention and treatment of carnitine deficiency in patients with end stage renal disease who are undergoing dialysis.

## **CONTRAINDICATIONS**

None known.

## **WARNINGS**

None.

## **PRECAUTIONS**

The safety and efficacy of oral levocarnitine has not been evaluated in patients with renal insufficiency. Chronic administration of high doses of oral levocarnitine in patients with severely compromised renal function or in ESRD patients on dialysis may result in accumulation of the potentially toxic metabolites, trimethylamine (TMA) and trimethylamine-N-oxide (TMAO), since these metabolites are normally excreted in the urine.

### **Carcinogenesis, mutagenesis, impairment of fertility**

Mutagenicity tests performed in *Salmonella typhimurium*, *Saccharomyces cerevisiae*, and *Schizosaccharomyces pombe* indicate that levocarnitine is not mutagenic. No long-term animal studies have been performed to evaluate the carcinogenic potential of levocarnitine.

### **Pregnancy**

#### **Pregnancy Category B.**

Reproductive studies have been performed in rats and rabbits at doses up to 3.8 times the human dose on the basis of surface area and have revealed no evidence of impaired fertility or harm to the fetus due to CARNITOR<sup>®</sup>. There are, however, no adequate and well controlled studies in pregnant women.

Because animal reproduction studies are not always predictive of human response, this drug should be used during pregnancy only if clearly needed.

### **Nursing Mothers**

Levocarnitine supplementation in nursing mothers has not been specifically studied.

Studies in dairy cows indicate that the concentration of levocarnitine in milk is increased following exogenous administration of levocarnitine. In nursing mothers receiving levocarnitine, any risks to the child of excess carnitine intake need to be weighed against the benefits of levocarnitine supplementation to the mother. Consideration may be given to discontinuation of nursing or of levocarnitine treatment.

### **Pediatric Use**

See Dosage and Administration.



**ADVERSE REACTIONS**

Transient nausea and vomiting have been observed. Less frequent adverse reactions are body odor, nausea, and gastritis. An incidence for these reactions is difficult to estimate due to the confounding effects of the underlying pathology.

Seizures have been reported to occur in patients, with or without pre-existing seizure activity, receiving either oral or intravenous levocarnitine. In patients with pre-existing seizure activity, an increase in seizure frequency and/or severity has been reported.

The table below lists the adverse events that have been reported in two double-blind, placebo-controlled trials in patients on chronic hemodialysis. Events occurring at  $\geq 5\%$  are reported without regard to causality.

**Adverse Events with a Frequency  $\geq 5\%$  Regardless of Causality by Body System**

	<i>Placebo</i> (n=63)	<i>Levocarnitine 10 mg</i> (n=34)	<i>Levocarnitine 20 mg</i> (n=62)	<i>Levocarnitine 40 mg</i> (n=34)	<i>Levocarnitine 10, 20 &amp; 40 mg</i> (n=130)
<b><i>Body as Whole</i></b>					
Abdominal pain	17	21	5	6	9
Accidental injury	10	12	8	12	10
Allergic reaction	5	6			2
Asthenia	8	9	8	12	9
Back pain	10	9	8	6	8
Chest pain	14	6	15	12	12
Fever	5	6	5	12	7
Flu syndrome	40	15	27	29	25
Headache	16	12	37	3	22
Infection	17	15	10	24	15
Injection site reaction	59	38	27	38	33
Pain	49	21	32	35	30
<b><i>Cardiovascular</i></b>					
Arrhythmia	5	3		3	2
Atrial fibrillation			2	6	2
Cardiovascular disorder	6	3	5	6	5

	<b>Plac e b o (n= 63)</b>	<b>Levoca r n i t i n e 10 mg (n=34)</b>	<b>Levoca r n i t i n e 20 mg (n=62)</b>	<b>Levoca r n i t i n e 40 mg (n=34)</b>	<b>Levoca r n i t i n e 10, 20 &amp; 40 mg (n=130 )</b>
Electrocardiogram abnormal		3		6	2
Hemorrhage	6	9	2	3	4
Hypertension	14	18	21	21	20
Hypotension	19	15	19	3	14
Palpitations		3	8		5
Tachycardia	5	6	5	9	6
Vascular disorder	2		2	6	2
<b><i>Digestive</i></b>					
Anorexia	3	3	5	6	5
Constipation	6	3	3	3	3
Diarrhea	19	9	10	35	16
Dyspepsia	10	9	6		5
Gastrointestinal disorder	2	3		6	2
Melena	3	6			2
Nausea	10	9	5	12	8
Stomach atony	5				
Vomiting	16	9	16	21	15
<b><i>Endocrine System</i></b>					
Parathyroid disorder	2	6	2	6	4
<b><i>Hemic/Lymphatic</i></b>					
Anemia	3	3	5	12	6
<b><i>Metabolic/Nutritional</i></b>					
Hypercalcemia	3	15	8	6	9
Hyperkalemia	6	6	6	6	6
Hypervolemia	17	3	3	12	5
Peripheral edema	3	6	5	3	5
Weight decrease	3	3	8	3	5

	<b>Plac e b o (n= 63)</b>	<b>Levoca r n i t i n e 10 mg (n=34)</b>	<b>Levoca r n i t i n e 20 mg (n=62)</b>	<b>Levoca r n i t i n e 40 mg (n=34)</b>	<b>Levoca r n i t i n e 10, 20 &amp; 40 mg (n=130 )</b>
Weight increase	2	3		6	2
<b><i>Musculo-Skeletal</i></b>					
Leg cramps	13		8		4
Myalgia	6				
<b><i>Nervous</i></b>					
Anxiety	5		2		1
Depression	3	6	5	6	5
Dizziness	11	18	10	15	13
Drug dependence	2	6			2
Hypertonia	5	3			1
Insomnia	6	3	6		4
Paresthesia	3	3	3	12	5
Vertigo		6			2
<b><i>Respiratory</i></b>					
Bronchitis			5	3	3
Cough increase	16		10	18	9
Dyspnea	19	3	11	3	7
Pharyngitis	33	24	27	15	23
Respiratory disorder	5				
Rhinitis	10	6	11	6	9
Sinusitis	5		2	3	2
<b><i>Skin And Appendages</i></b>					
Pruritus	13		8	3	5
Rash	3		5	3	3
<b><i>Special Senses</i></b>					
Amblyopia	2		6		3
Eye disorder	3	6	3		3
Taste perversion			2	9	3

	<b>Plac ebo (n=63)</b>	<b>Levoca rnitine 10 mg (n=34)</b>	<b>Levoca rnitine 20 mg (n=62)</b>	<b>Levoca rnitine 40 mg (n=34)</b>	<b>Levoca rnitine 10, 20 &amp; 40 mg (n=130 )</b>
<b><i>Urogenital</i></b>					
Urinary tract infect	6	3	3		2
Kidney failure	5	6	6	6	6

## OVERDOSAGE

There have been no reports of toxicity from levocarnitine overdosage. Levocarnitine is easily removed from plasma by dialysis. The intravenous LD<sub>50</sub> of levocarnitine in rats is 5.4 g/kg and the oral LD<sub>50</sub> of levocarnitine in mice is 19.2 g/kg. Large doses of levocarnitine may cause diarrhea.

## DOSAGE AND ADMINISTRATION

CARNITOR<sup>®</sup> Injection is administered intravenously.

### *Metabolic Disorders*

The recommended dose is 50 mg/kg given as a slow 2-3 minute bolus injection or by infusion. Often a loading dose is given in patients with severe metabolic crisis, followed by an equivalent dose over the following 24 hours. It should be administered q3h or q4h, and never less than q6h either by infusion or by intravenous injection. All subsequent daily doses are recommended to be in the range of 50 mg/kg or as therapy may require. The highest dose administered has been 300 mg/kg.

It is recommended that a plasma carnitine concentration be obtained prior to beginning this parenteral therapy. Weekly and monthly monitoring is recommended as well. This monitoring should include blood chemistries, vital signs, plasma carnitine concentrations (the plasma free carnitine concentration should be between 35 and 60 µmol/L) and overall clinical condition.

### *ESRD Patients on Hemodialysis*

The recommended starting dose is 10-20 mg/kg dry body weight as a slow 2-3 minute bolus injection into the venous return line after each dialysis session. Initiation of therapy may be prompted by trough (pre-dialysis) plasma levocarnitine concentrations that are below normal (40-50 µmol/L). Dose adjustments should be guided by trough (pre-dialysis) levocarnitine concentrations, and downward dose adjustments (e.g. to 5 mg/kg after dialysis) may be made as early as the third or fourth week of therapy.

***Parenteral drug products should be inspected visually for particulate matter and discoloration prior to administration, whenever solution and container permit.***

## COMPATIBILITY AND STABILITY

CARNITOR<sup>®</sup> Injection is compatible and stable when mixed in parenteral solutions of Sodium Chloride 0.9% or Lactated Ringer's in concentrations ranging from 250 mg/500 mL (0.5 mg/mL) to 4200 mg/500

mL (8.0 mg/mL) and stored at room temperature (25°C) for up to 24 hours in PVC plastic bags.

### HOW SUPPLIED

CARNITOR<sup>®</sup> (levocarnitine) Injection is available in 1 g per 5 mL single dose vials packaged 5 vials per carton (NDC 54482-147-01). CARNITOR<sup>®</sup> (levocarnitine) Injection 5 mL vial is manufactured for Sigma-Tau Pharmaceuticals, Inc. by Chesapeake Biological Laboratories, Inc. Baltimore, MD 21230-2591.

Store vials at controlled room temperature (25°C). See USP. Discard unused portion of an opened vial, as the formulation does not contain a preservative.

CARNITOR<sup>®</sup> (levocarnitine) is also available in the following dosage forms:

CARNITOR<sup>®</sup> (levocarnitine) Injection is available in 1 g per 5 mL single dose ampoules packaged 5 ampoules per carton (NDC 54482-146-09). Made in Italy.

CARNITOR<sup>®</sup> (levocarnitine) Tablets are supplied as 330 mg tablets embossed with “CARNITOR ST” in blister packages, in boxes of 90 tablets (NDC 54482-144-07). Made in Italy.

CARNITOR<sup>®</sup> (levocarnitine) Oral Solution is supplied in 118 mL (4 FL. OZ.) multiple-unit plastic containers. The multiple-unit containers are packaged 24 per case (NDC 54482-145-08). CARNITOR<sup>®</sup> (levocarnitine) Oral Solution is manufactured for Sigma-Tau Pharmaceuticals, Inc. by Alpharma USPD, Inc., Baltimore, MD 21244-2654 and/or Hi-Tech Pharmacal Co., Inc., Amityville, NY 11701.


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### REFERENCES

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