UREA CYCLE DISORDERS DON’T AFFECT JUST NEONATES

NAGS deficiency may occur at any time of life [1]

INDICATIONS AND USAGE

Carbaglu® (carglumic acid) is a Carbamoyl Phosphate Synthetase 1 (CPS1) activator indicated as:

- **Adjunctive therapy** in pediatric and adult patients for the treatment of acute hyperammonemia due to the deficiency of the hepatic enzyme N-acetylglutamate synthase (NAGS). During acute hyperammonemic episodes, concomitant administration of CARBAGLU with other ammonia lowering therapies, such as alternate pathway medications, hemodialysis, and dietary protein restriction, is recommended.

- **Maintenance therapy** in pediatric and adult patients for chronic hyperammonemia due to the deficiency of the hepatic enzyme N-acetylglutamate synthase (NAGS). During maintenance therapy, the concomitant use of other ammonia lowering therapies and protein restriction may be reduced or discontinued based on plasma ammonia levels.

IMPORTANT SAFETY INFORMATION

The most common adverse reactions in ≥13% of patients are: infections, vomiting, abdominal pain, pyrexia, tonsillitis, anemia, ear infection, diarrhea, nasopharyngitis, and headache.
UREA CYCLE AND DEFECTS

- In humans, nitrogen is produced by catabolism of proteins and excreted through the urea cycle [1]
- The urea cycle converts waste nitrogen into ammonium [1]
- Deficiency of enzymes in the urea cycle leads to a build-up of ammonium which is neurotoxic [1]

**NAGS**: N-acetylglutamate synthase
**CPS1**: carbamoyl phosphate synthetase 1
**OTC**: ornithine transcarbamylase
**ASS**: argininosuccinate synthetase
**ASL**: argininosuccinate lyase
**ARG**: arginase

*Interruption of the urea cycle causes hyperammonemia which, if untreated, may result in coma and death [1]*

*The mortality rate during hyperammonemic crises can reach 10% [1]*
Genetic testing is the method of choice to confirm the diagnosis of NAGS deficiency.\textsuperscript{[4]} For more information consult the National Center for Biotechnology Information (NCBI) Genetic Testing Registry at www.ncbi.nlm.nih.gov/gtr
**NAGS DEFICIENCY**

- NAGS deficiency is a rare autosomal recessive urea cycle disorder \[1\]
- The classic presentation of urea cycle disorders including primary NAGS deficiency is high levels of ammonia in the neonatal period (inherited NAGS activity deficiency) \[2\]
- Partial/milder enzyme deficiency may permit an individual to function normally until a stress factor triggers a hyperammonemic crisis: \[2\]
  - Valproic acid | Heart-lung transplant | Parenteral nutrition with high nitrogen intake
  - Post-partum stress | Short bowel and kidney disease | Gastrointestinal bleeding

**NAGS DEFICIENCY IN LATE-ONSET PATIENTS:**

**CLINICAL PRESENTATION**

<table>
<thead>
<tr>
<th>FINDINGS IN REPORTED CASES OF CONFIRMED NAGS DEFICIENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GASTROINTESTINAL PRESENTATIONS</strong></td>
</tr>
<tr>
<td>- Nausea and vomiting [1,3]</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
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</tr>
</tbody>
</table>

**BLOOD AMMONIA 138-4781 µmol/L* \[1\]**

* Normal blood ammonia levels in adults: 15-55 µmol/L \[1\]
**DIAGNOSTIC CLUES AND MANAGEMENT**

- Plasma ammonia should be measured promptly in all patients with unexplained encephalopathy, including cyclical manifestations, to identify potential underlying metabolic disorders [1].
- Prompt diagnosis and initiation of treatment are necessary to avoid potentially poor neurological outcomes [5].
- Management of these patients requires a multidisciplinary approach by physicians caring for adults, dieticians, social workers and genetic counsellors [1].
- The mainstay of ongoing management of NAGS deficiency is maintenance of plasma ammonia levels in a normal range by avoiding catabolic stress and using specific treatments:
  - Carglumic acid is the specific treatment for NAGS deficiency [1,7].
  - Carglumic acid allows a more liberal protein intake [1,7].

**IMPORTANT SAFETY INFORMATION**

**HYPERAMMONEMIA:**

- Management of hyperammonemia due to N-acetylglutamate synthase (NAGS) deficiency and Carbaglu® (carglumic acid) treatment should be initiated by a physician experienced in the treatment of metabolic disorders.
- Any episode of acute symptomatic hyperammonemia should be treated as a life-threatening emergency. Treatment of hyperammonemia may require dialysis, preferably hemodialysis, to remove a large burden of ammonia. Uncontrolled hyperammonemia can rapidly result in brain injury/damage or death, and prompt use of all therapies necessary to reduce plasma ammonia levels is essential.
- Ongoing monitoring of plasma ammonia levels, neurological status, laboratory tests and clinical responses in patients receiving CARBAGLU is crucial to assess patient response to treatment.

**THERAPEUTIC MONITORING:**

- Plasma ammonia levels should be maintained within normal range for age via individual dose adjustment.

**NUTRITIONAL MANAGEMENT:**

- Since hyperammonemia is the result of protein catabolism, complete protein restriction is recommended to be maintained for 24 to 48 hours and caloric supplementation should be maximized to reverse catabolism and nitrogen turnover.

No drug interaction studies have been performed with CARBAGLU. There is no human pregnancy data, but decreased survival and growth occurred in animal offspring.

Breast feeding by a mother taking CARBAGLU is not recommended.

USE IN OTHER FOODS AND LIQUIDS HAS NOT BEEN STUDIED CLINICALLY AND IS THEREFORE NOT RECOMMENDED.
### ILLUSTRATIVE CASE OF NAGS DEFICIENCY DIAGNOSED IN A 38-YEAR OLD MALE [1]

20-year history of fluctuating behavioral changes associated with nausea and vomiting

#### Past medical history

| Symptomatic (behavioral changes, confusion) in early childhood and adulthood | Ammonia levels never checked before hospitalization | Negative family history |

#### Clinical course... in the emergency room

<table>
<thead>
<tr>
<th>Ongoing nausea, vomiting, headache</th>
<th>Stable vital signs</th>
<th>Behavioral disinhibition and fluctuating drowsiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impaired coordination</td>
<td>Normal cranial nerve examination and power testing</td>
<td>Otherwise unremarkable general examination</td>
</tr>
</tbody>
</table>
| Mild spasticity on muscle tone assessment | Significant asterixis (flapping tremor) | }

#### ... during hospital admission and follow-up

<table>
<thead>
<tr>
<th>High blood ammonia levels 434 µmol/L</th>
<th>Mild respiratory alkalosis</th>
<th>Normal head/spine MRI</th>
</tr>
</thead>
</table>
| Continuous EEG monitoring: generalized encephalopathy | Elevated glutamine level (1062 µmol/L), normal citrulline and urine amino acid levels | }

#### Diagnosis

Molecular sequencing of the NAGS gene: compound heterozygote for E433G and IVS6+5 G>A, (both mutations) with residual NAGS expression that explains the absence of neonatal hyperammonemia and delayed presentation in adult life

#### Medical management

| Low protein diet | Initially sodium phenylbutyrate (200 mg TID*) and citrulline (50 mg/kg TID) | Switched to carglumic acid (1200 mg TID) with a liberalized protein intake |

#### Outcome

| Ammonia level returned to normal (29-35 µmol/L) | No hyperammonemic crisis for 2 years | Markedly improved behavior; short term memory loss remains |

* TID: three times a day

### IMPORTANT SAFETY INFORMATION

The most common adverse reactions in ≥13% of patients are: infections, vomiting, abdominal pain, pyrexia, tonsillitis, anemia, ear infection, diarrhea, nasopharyngitis, and headache.

To report SUSPECTED ADVERSE REACTIONS, contact Recordati Rare Diseases Inc. at 1-888-575-8344, or FDA at 1-800-FDA-1088 or www.fda.gov/medwatch.
IMPORTANT SAFETY INFORMATION

HYPERAMMONEMIA:

- Management of hyperammonemia due to N-acetylglutamate synthase (NAGS) deficiency and Carbaglu® (carglumic acid) treatment should be initiated by a physician experienced in the treatment of metabolic disorders.
- Any episode of acute symptomatic hyperammonemia should be treated as a life-threatening emergency. Treatment of hyperammonemia may require dialysis, preferably hemodialysis, to remove a large burden of ammonia. Uncontrolled hyperammonemia can rapidly result in brain injury/damage or death, and prompt use of all therapies necessary to reduce plasma ammonia levels is essential.
- Ongoing monitoring of plasma ammonia levels, neurological status, laboratory tests and clinical responses in patients receiving CARBAGLU is crucial to assess patient response to treatment.

THERAPEUTIC MONITORING:

- Plasma ammonia levels should be maintained within normal range for age via individual dose adjustment.

NUTRITIONAL MANAGEMENT:

- Since hyperammonemia is the result of protein catabolism, complete protein restriction is recommended to be maintained for 24 to 48 hours and caloric supplementation should be maximized to reverse catabolism and nitrogen turnover.

The most common adverse reactions in \( \geq 13\% \) of patients are: infections, vomiting, abdominal pain, pyrexia, tonsillitis, anemia, ear infection, diarrhea, nasopharyngitis, and headache.

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No drug interaction studies have been performed with CARBAGLU. There is no human pregnancy data, but decreased survival and growth occurred in animal offspring.

Breast feeding by a mother taking CARBAGLU is not recommended.

USE IN OTHER FOODS AND LIQUIDS HAS NOT BEEN STUDIED CLINICALLY AND IS THEREFORE NOT RECOMMENDED.

REFERENCES

7. CARBAGLU Prescribing Information, Recordati Rare Diseases Inc., 2015.
Carbaglu® (carglumic acid)

Exclusive Distribution Through Accredo
Representatives at Accredo Health Group, Inc. are committed to helping you and your patients through the ordering process. CARBAGLU is not available in retail pharmacies.

Patient Home Delivery
1. Download the CARBAGLU Prescription & Enrollment Form from the Accredo website (www.accredo.com).
2. Complete the CARBAGLU Prescription & Enrollment Form and fax it to the Accredo specialty pharmacy department at 1-888-454-8488.
3. A CARBAGLU specialty pharmacy representative may call to verify information and determine next steps. In some cases, prior authorization may be necessary.
4. Questions? Contact a CARBAGLU specialty pharmacy representative at 1-888-454-8860.

Hospital Orders – Emergency or Inpatient
1. Alert your hospital pharmacy that your patient requires CARBAGLU. Send an order for CARBAGLU to your hospital pharmacy and specify whether it is a STAT order (required in 6 hours or less*).
2. Ask your hospital pharmacy to call the wholesale department at Accredo at 1-877-900-9223 to place the order.
3. The wholesale department at Accredo will work with your hospital pharmacy to obtain payment information, establish shipping timelines, and verify the delivery address.
4. The Accredo specialty pharmacy team will follow up in 1-2 days to help set up patient home delivery of CARBAGLU, if applicable.

*Delivery time frame is weather dependent and is not guaranteed.

FINANCIAL ASSISTANCE PROGRAMS
For patients experiencing financial hardship, Recordati Rare Diseases Inc. supports a Patient Assistance Program and a Co-Pay Assistance Program, administered by Accredo. For more information, call: 1-888-454-8860.

For more information about CARBAGLU, visit: www.carbaglu.net
N-acetylglutamate synthase (NAGS). During acute hyperammonemic episodes (carglumic acid) tablets

Carbaglu® is a Carbamoyl Phosphate Synthetase 1 (CPS 1) activator indicated as:

- Adjunctive therapy for the treatment of acute hyperammonemia due to the deficiency of the hepatic enzyme N-acetylglutamate synthase (NAGS) (1.1)
- Maintenance therapy for the treatment of chronic hyperammonemia due to the deficiency of the hepatic enzyme N-acetylglutamate synthase (NAGS) (1.2)

**DOSAGE AND ADMINISTRATION**

**Carbaglu® treatment** should be initiated by a physician experienced in metabolic disorders

**Adult Dosage and Administration**

- Recommended initial dose range for acute hyperammonemia is 100 mg/kg/day to 250 mg/kg/day (2.1)
- Adjust the dose to maintain normal plasma ammonia levels based on age (2.1)
- Divide the total daily dose into two to four doses to be given immediately before meals or feedings (2.1)
- Each divided dose should be rounded to the nearest 100 mg (2.1)
- Each 200 mg tablet should be dispersed in a minimum of 2.5 mL of water and taken immediately (2.2)
- Carbaglu® can be administered orally or through a nasogastric tube (2.3)
- Carbaglu® tablets should not be swallowed whole or crushed (2.2)

**Pediatric Dosage and Administration**

- Recommended initial dose range for acute hyperammonemia is 100 mg/kg/day to 250 mg/kg/day (2.4)
- The recommended maintenance dose should be titrated to target normal plasma ammonia levels for age (2.4)

**5.4 Therapeutic Monitoring**

**Therapeutic Monitoring**

Plasma ammonia levels should be maintained within normal range for age 

**ADVERSE REACTIONS**

The most common adverse reactions in ≥13% of patients are:

- Infections: conjunctivitis, rhinitis, pharyngitis
- Gastrointestinal: nausea, vomiting, abdominal pain, diarrhea
- Cardiovascular: hypertension
- Other: weight decrease

**Contraindications**

None.

**Warnings and Precautions**

- Hypersensitivity: Monitor plasma ammonia levels during treatment. Prolonged exposure to elevated plasma ammonia levels can rapidly result in injury to the brain or death. Prompt use of all therapies necessary to reduce plasma ammonia levels is essential. (5.1)
- Therapeutic Monitoring: Plasma ammonia levels should be maintained within normal range for age via individual dose adjustment. (5.2)
- Nutritional Management: In the initial treatment of NAGS deficiency, protein restriction is recommended. When plasma ammonia level is normalized, dietary protein intake can usually be reintroduced. (5.3)

**DRUG INTERACTIONS**

No drug interactions have been identified. (7)

**Use in Specific Populations**

- Pregnancy: No human data; decreased survival and growth in animal offspring. (8.1)
- Nursing Mothers: Human milk-feeding is not recommended. (8.3)

See 17 for Patient Counseling Information

Revised: 11/2015
recommended. Dosing should be titrated based on individual patient plasma ammonia levels and clinical symptoms.

The recommended maintenance dose should be titrated to target normal plasma ammonia level for age. Based on limited data in 22 patients receiving maintenance treatment with Carbaglu® in a retrospective case series, maintenance doses were usually less than 100 mg/kg/day.

The total daily dose should be divided into 2 to 4 doses.

2.5 Preparation for Oral Administration Using an Oral Syringe in Pediatrics

For administration via oral syringe, Carbaglu® should be administered as follows:
• Mix each 200 mg tablet in 2.5 mL of water to yield a concentration of 80 mg/mL in a mixing container. Shake gently to allow for quick dispersal.
• Draw up the appropriate volume of dispersion in an oral syringe and administer immediately.
• Refill the oral syringe with a minimum volume of water (1-2 mL) and administer immediately.

2.6 Preparation for Nasogastric Tube Administration in Pediatrics

For patients who have a nasogastric tube in place, Carbaglu® should be administered as follows:
• Mix each 200 mg tablet in 2.5 mL of water to yield a concentration of 80 mg/mL in a mixing container. Shake gently to allow for quick dispersal.
• Draw up the appropriate volume of dispersion and administer immediately through a nasogastric tube. Discard the unused portion.

USE IN OTHER FOODS AND LIQUIDS HAS NOT BEEN STUDIED CLINICALLY AND IS THEREFORE NOT RECOMMENDED.

3 DOSE FORMS AND STRENGTHS

Carbaglu® is a white and elongated 200 mg tablet, scored and coded “C” on one side.

4 CONTRAINDICATIONS

None

5 WARNINGS AND PRECAUTIONS

5.1 Hyperammonemia

Any episode of acute symptomatic hyperammonemia should be treated as a life-threatening emergency. Treatment of hyperammonemia may require dialysis, preferably hemodialysis, to remove a large burden of ammonia. Uncontrolled hyperammonemia can rapidly result in brain injury/damage or death, and prompt use of all therapies necessary to reduce plasma ammonia levels is essential.

Management of hyperammonemia due to NAGS deficiency should be done in coordination with other specific therapies experienced in metabolic disorders.

Ongoing monitoring of plasma ammonia levels, neurological status, laboratory tests and clinical responses in patients receiving Carbaglu® is crucial to assess patient response to treatment.

5.2 Therapeutic Monitoring

Plasma ammonia levels should be maintained within normal range for age via individual dose adjustment.

5.3 Nutritional Management

Since hyperammonemia is the result of protein catabolism, complete protein restriction is recommended to be maintained for 24 to 48 hours and caloric supplementation should be maximized to reverse catabolism and nitrogen turnover.

6 ADVERSE REACTIONS

6.1 Retrospective Case Series Experience

The most common adverse reactions (occurring in ≥ 13% of patients), regardless of causality, are: Infections, vomiting, abdominal pain, pyrexia, tonsillitis, anemia, ear infection, diarrhea, nasopharyngitis and headache.

Table 1 summarizes adverse reactions occurring in 2 or more patients treated with Carbaglu® in the retrospective case series. Because these reactions were reported retrospectively, it is not always possible to reliably estimate their frequency or establish a causal relationship to drug exposure.

Table 1. Adverse Reactions Reported in ≥ 2 Patients in the Retrospective Case Series Treated with Carbaglu®

<table>
<thead>
<tr>
<th>Preferred Term</th>
<th>Number of Patients</th>
<th>(N)(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anemia</td>
<td>3 (13)</td>
<td></td>
</tr>
<tr>
<td>Ear and labyrinth disorders</td>
<td>3 (13)</td>
<td></td>
</tr>
<tr>
<td>Gastrointestinal disorders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdominal pain</td>
<td>4 (17)</td>
<td></td>
</tr>
<tr>
<td>Diarrhea</td>
<td>3 (13)</td>
<td></td>
</tr>
<tr>
<td>Vomiting</td>
<td>6 (26)</td>
<td></td>
</tr>
<tr>
<td>Dysgeusia</td>
<td>2 (9)</td>
<td></td>
</tr>
<tr>
<td>General disorders and administration site conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asthma</td>
<td>2 (9)</td>
<td></td>
</tr>
<tr>
<td>Hyperhidrosis</td>
<td>2 (9)</td>
<td></td>
</tr>
<tr>
<td>Pyrexia</td>
<td>4 (17)</td>
<td></td>
</tr>
</tbody>
</table>

System Organ Class

<table>
<thead>
<tr>
<th>Preferred Term</th>
<th>Number of Patients</th>
<th>(N)(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood and lymphatic system disorders</td>
<td>23 (100)</td>
<td></td>
</tr>
<tr>
<td>Eye</td>
<td>1 (4)</td>
<td></td>
</tr>
<tr>
<td>Ear</td>
<td>3 (13)</td>
<td></td>
</tr>
<tr>
<td>Gastrointestinal disorders</td>
<td>14 (62)</td>
<td></td>
</tr>
<tr>
<td>Abdominal pain</td>
<td>7 (31)</td>
<td></td>
</tr>
<tr>
<td>Diarrhea</td>
<td>12 (52)</td>
<td></td>
</tr>
<tr>
<td>Vomiting</td>
<td>19 (83)</td>
<td></td>
</tr>
<tr>
<td>General disorders and administration site conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asthma</td>
<td>1 (4)</td>
<td></td>
</tr>
<tr>
<td>Hyperhidrosis</td>
<td>1 (4)</td>
<td></td>
</tr>
<tr>
<td>Pyrexia</td>
<td>11 (47)</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>25 (100)</td>
<td></td>
</tr>
</tbody>
</table>

7 DRUG INTERACTIONS

Based on in-vitro studies, Carbaglu® is not an inducer of CYP1A2, CYP2B6, CYP2C, and CYP3A4/5 enzymes and not an inhibitor of CYP1A2, CYP2B6, CYP2C9, CYP2D6, CYP2C19, CYP2D6, CYP2E1, and CYP3A4/5 enzymes.

8 USE IN SPECIFIC POPULATIONS

8.1 Pregnancy

Pregnancy Category C

There are no adequate and well controlled studies or available human data with Carbaglu® in pregnant women. Decreased survival and growth occurred in offspring born to animals that received carglumic acid at doses similar to the maximum recommended starting human dose during pregnancy and lactation. Because untreated N-acetylglutamate synthase (NAGS) deficiency results in irreversible neurologic damage and death, women with NAGS must remain on treatment throughout pregnancy.

In embryo-fetal developmental toxicity studies, pregnant rats and rabbits received oral carglumic acid during organogenesis at doses up to 1.3 times the maximum recommended starting dose based on body surface area (mg/m²). Actual doses were 500 and 2000 mg/kg/day (rats) and 250 and 1000 mg/kg/day (rabbits). The high doses resulted in maternal toxicity in both rats and rabbits. No effects on embryo-fetal development were observed in either species.

In a peri- and post-natal developmental study, female rats received oral carglumic acid from organogenesis through day 21 post-partum at doses up to 1.3 times the maximum recommended starting human dose based on body surface area (mg/m²). Actual doses were 500 and 2000 mg/kg/day (rats) and 250 and 1000 mg/kg/day (rabbits). A reduction in offspring survival was seen at the high dose and a reduction in offspring growth was seen at both doses.

8.3 Nursing Mothers

It is not known whether Carbaglu® is excreted in human milk. Carglumic acid is excreted in rat milk, and an increase in mortality and impairment of body weight gain occurred in neonatal rats nursed by mothers receiving carglumic acid. Because many drugs are excreted in human milk and because of the potential for serious adverse reactions in nursing infants from Carbaglu®, human milk-feeding is not recommended. Treatment is continuous and life-long for NAGS deficiency patients.

8.4 Pediatric Use

The efficacy of Carbaglu® for the treatment of hyperammonemia in patients with NAGS deficiency from birth to adulthood was evaluated in a retrospective review of the clinical course of 23 NAGS deficiency patients who all began Carbaglu® treatment during infancy or childhood. There are no apparent differences in clinical response between adults and pediatric NAGS deficiency patients treated with Carbaglu®, however, data are limited.

8.5 Geriatric Use

Carbaglu® has not been studied in the geriatric population. Therefore, the safety and effectiveness in geriatric patients have not been established.

10 OVERDOSE

One patient treated with 650 mg/kg/day of carglumic acid developed symptoms characterized as a monosodium glutamate intoxication-like syndrome: tachycardia, profuse sweating, increased bronchial secretion, increased body temperature and restlessness. These symptoms resolved upon reduction of dose.

Repeated oral dosing of carglumic acid at 2000 mg/kg/day was lethal to most neonatal rats within 2-3 days of treatment. In adult rats, a single oral administration of carglumic acid was not lethal at doses up to 2800 mg/kg (1.8 times the maximum recommended starting dose based on a body surface area comparison to adult humans).

11 DESCRIPTION

Carbaglu® tablets for oral administration contain 200 mg of carglumic acid. Carglumic acid, the active substance, is a Carbamoyl Phosphate Synthetase 1 (CPS 1) activator and is soluble in boiling water, slightly soluble in cold water, practically insoluble in organic solvents.

Chemically carglumic acid is N-carbamoyl-L-glutamic acid or (2S)-2-(carbamoylamino)pentanedioic acid, with a molecular weight of 190.16.
The structural formula is:

\[
\text{H}_2\text{N}-\text{N}^+\text{HO}^-\text{OH}
\]

Molecular Formula: C\(_6\)H\(_{10}\)N\(_2\)O\(_5\)

The inactive ingredients of Carbaglu\(^\text{a}\) are microcrystalline cellulose, sodium lauryl sulfate, hypromellose, croscarmellose sodium, silica colloidal anhydrous, sodium stearyl fumarate.

### 12 CLINICAL PHARMACOLOGY

#### 12.1 Mechanism of Action

Carglumic acid is a synthetic structural analogue of N-acetylglutamate (NAG), which is an essential allosteric activator of carbamoyl phosphate synthetase 1 (CPS 1) in liver mitochondria. CPS 1 is the first enzyme of the urea cycle, which converts ammonia into urea. NAG is the product of N-acetylglutamate synthase (NAGS), a mitochondrial enzyme. Carglumic acid acts as a replacement for NAG in NAGS deficiency patients by activating CPS 1.

#### 12.2 Pharmacodynamics

In a retrospective review of the clinical course in 23 patients with NAGS deficiency, carglumic acid reduced plasma ammonia levels within 24 hours when administered with and without concomitant ammonia lowering therapies. No dose response relationship has been identified.

#### 12.3 Pharmacokinetics

The pharmacokinetics of carglumic acid have been studied in healthy male volunteers using both radiolabeled and non-radiolabeled carglumic acid.

**Absorption**

The median Tmax of Carbaglu\(^\text{a}\) was 3 hours (range: 2-4). Absolute bioavailability has not been determined.

**Distribution**

The apparent volume of distribution was 2657 L (range: 1616-5797). Protein binding has not been determined.

**Metabolism**

A proportion of carglumic acid may be metabolized by the intestinal bacterial flora. The likely end product of carglumic acid metabolism is carbon dioxide, eliminated through the lungs.

**Elimination**

Median value for the terminal half-life was 5.6 hours (range 4.3-9.5), the apparent total clearance was 5.7 L/min (range 3.0-9.7), the renal clearance was 290 mL/min (range 204-445), and the 24-hour urinary excretion was 4.5% of the dose (range 3.5-7.5). Following administration of a single radiolabeled oral dose of 100 mg/kg of body weight, 9% of the dose was excreted unchanged in the urine and up to 60% of the dose was excreted unchanged in the feces.

**Drug Interaction Studies**

No drug interaction studies have been performed. Based on *in-vitro* studies, Carbaglu\(^\text{a}\) is not an inducer of CYP1A2, CYP2B6, CYP2C, and CYP3A4/5 enzymes, and not an inhibitor of CYP1A2, CYP2A6, CYP2B6, CYP2C8, CYP2C9, CYP2D6, CYP2E1, and CYP3A4/5 enzymes.

### 13 NONCLINICAL TOXICOLOGY

#### 13.1 Carcinogenesis, Mutagenesis, Impairment of Fertility

Carcinogenicity studies have not been performed with carglumic acid.

Carglumic acid was negative in the Ames test, chromosomal aberration assay in human lymphocytes, and the in vivo micronucleus assay in rats. There were no effects on fertility or reproductive performance in male rats at oral doses up to 1000 mg/kg/day (0.6 times the maximum recommended human starting dose based on body surface area). In a separate study, mating and fertility were unaffected in male rats at oral doses up to 1000 mg/kg/day (0.8 times the maximum recommended human starting dose based on body surface area).

### 14 CLINICAL STUDIES

#### 14.1 Responses of Patients with NAGS Deficiency to Acute and Chronic Treatment

The efficacy of Carbaglu\(^\text{a}\) in the treatment of hyperammonemia due to NAGS deficiency was evaluated in a retrospective review of the clinical course of 23 NAGS deficiency patients who received Carbaglu\(^\text{a}\) treatment for a median of 7.9 years (range 0.6 to 20.8 years).

The demographics characteristics of the patient population are shown in Table 2.

#### Table 2. Baseline Characteristics of the 23 NAGS deficiency patients

<table>
<thead>
<tr>
<th>Gender</th>
<th>Patients N=23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>14 (61%)</td>
</tr>
<tr>
<td>Female</td>
<td>9 (39%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age at initiation of Carbaglu(^\text{a}) therapy (years)</th>
<th>Patients N=23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD)</td>
<td>2 (4)</td>
</tr>
<tr>
<td>Min-Max</td>
<td>0-13</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age groups at initiation of Carbaglu(^\text{a}) therapy</th>
<th>Patients N=23</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 30 days</td>
<td>9 (39%)</td>
</tr>
<tr>
<td>30 days - 11 months</td>
<td>9 (39%)</td>
</tr>
<tr>
<td>1 - 13 years</td>
<td>5 (22%)</td>
</tr>
</tbody>
</table>

The clinical observations in the 23 patient case series were retrospective, unblinded and uncontrolled and preclude any meaningful formal statistical analyses of the data. However, short-term efficacy was evaluated using mean and median change in plasma ammonia levels from baseline to days 1 to 3. Persistence of efficacy was evaluated using long-term mean and median change in plasma ammonia level. Table 3 summarizes the plasma ammonia levels at baseline, days 1 to 3 post-Carbaglu\(^\text{a}\) treatment, and long-term Carbaglu\(^\text{a}\) treatment for 13 evaluable patients. Of the 23 NAGS deficiency patients who received treatment with Carbaglu\(^\text{a}\), a subset of 13 patients who had both well documented plasma ammonia levels prior to Carbaglu\(^\text{a}\) treatment and after long-term treatment with Carbaglu\(^\text{a}\) were selected for analysis.

All 13 patients had abnormal ammonia levels at baseline. The overall mean baseline plasma ammonia level was 271 μmol/L. By day 3, normal plasma ammonia levels were attained in patients for whom data were available. Long-term efficacy was measured using the last reported plasma ammonia level for each of the 13 patients (median length of treatment was 6 years; range 1 to 16 years). The mean and median ammonia levels were 23 μmol/L and 24 μmol/L, respectively, after a mean treatment duration of 8 years.

#### Table 3. Plasma ammonia levels at baseline and after treatment with Carbaglu\(^\text{a}\)

<table>
<thead>
<tr>
<th>Timepoint (prior to first treatment with Carbaglu(^\text{a}))</th>
<th>Statistics (N = 13(^*))</th>
<th>Ammonia (^*) (μmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>Mean (SD) 271 (359)</td>
<td>25-1190</td>
</tr>
<tr>
<td>Day 2</td>
<td>Mean (SD) 69 (78)</td>
<td>11-255</td>
</tr>
<tr>
<td>Day 3</td>
<td>Mean (SD) 27 (11)</td>
<td>9-34</td>
</tr>
<tr>
<td>Long-term Mean (SD)</td>
<td>23 (7)</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>

* 1/23 patients with complete short-term and long-term plasma ammonia documentation
** Mean ammonia normal range: 5 to 50 μmol/L

The mean plasma ammonia level at baseline and the decline that is observed after treatment with Carbaglu\(^\text{a}\) in 13 evaluable patients with NAGS deficiency is illustrated in Figure 1.

#### Figure 1: Ammonia response for 13 evaluable NAGS deficiency patients at baseline and after treatment with Carbaglu\(^\text{a}\)
16 HOW SUPPLIED/STORAGE AND HANDLING

How Supplied

Carbaglu® is a white and elongated tablet, scored and coded “C” on one side. Each tablet contains 200 mg of carglumic acid. Carbaglu® is available in 5 or 60 tablets in a polypropylene bottle with polyethylene cap and desiccant unit.

NDC 52276-312-05 Bottles of 5 tablets
NDC 52276-312-60 Bottles of 60 tablets

Storage

Before opening, store refrigerated at 2 – 8°C (36 – 46°F).

After first opening of the container:
• Do not refrigerate, do not store above 30°C (86°F).
• Keep the container tightly closed in order to protect from moisture.
• Write the date of opening on the tablet container.
• Do not use after the expiration date stated on the tablet container.
• Discard one month after first opening.

17 PATIENT COUNSELING INFORMATION

Physicians should inform patients and caregivers about the following instructions for safe use of Carbaglu®:
• Carbaglu® tablets should not be swallowed whole or crushed. Each tablet should be dispersed in a minimum of 2.5 mL of water. Carbaglu® tablets do not dissolve completely in water and undissolved particles of the tablet may remain in the mixing container. The mixing container should be rinsed with additional volumes of water and the contents swallowed immediately.
• Before opening, store in a refrigerator 2 to 8°C (36 to 46°F).
• Keep the container tightly closed in order to protect from moisture.
• After first opening of the container: do not refrigerate, do not store above 30°C (86°F).
• Write the date of opening on the tablet container. Discard one month after first opening.
• Do not use after the expiration date stated on the tablet container.

Physicians should also advise patients and caregivers that:
• When plasma ammonia levels have normalized, dietary protein intake can usually be increased with the goal of unrestricted protein intake.
• Human milk-feeding is not recommended.
• The most common adverse reactions are infections, vomiting, abdominal pain, pyrexia, tonsillitis, anemia, ear infection, diarrhea, nasopharyngitis, and headache.

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