THERAPEUTICAL USES OF ESLICARBAZEPINE

This invention relates to drug therapies. More particularly the invention relates to the therapeutical use of eslicarbazepine and eslicarbazepine acetate.

As used in the specification the term "eslicarbazepine acetate" means (S)-(-)-10-acetoxy-10,11-dihydro-5H-dibenz/b,f/azepine-5-carboxamide. Also as used in this specification the term eslicarbazepine or S-licarbazepine means (S)-(+)-10,11-dihydro-10-hydroxy-5H dibenz/b,f/azepine-5-carboxamide.

Eslicarbazepine acetate, (S)-(-)-10-acetoxy-10,11-dihydro-5H-dibenz/b,f/azepine-5-carboxamide, is a new drug currently being developed which is useful for the treatment of various conditions, such as, for example, epilepsy and affective brain disorders, as well as pain conditions and nervous function alterations in degenerative and post-ischemic diseases. Although chemically related to carbamazepine and oxcarbazepine, eslicarbazepine acetate is believed to avoid the production of certain toxic metabolites (such as, for example, epoxides) and to avoid the unnecessary production of enantiomers or diastereoisomers of metabolites and conjugates, without losing pharmacological activity (Almeida et al., 2005a; Almeida et al., 2005b; Almeida et al., 2002; Almeida et al., 2003; Almeida et al., 2004; Benes et al., 1999; Bialer et al., 2004; Soares-da-Silva, 2004). Unlike oxcarbazepine, eslicarbazepine acetate is almost entirely metabolized to the active metabolite eslicarbazepine (Almeida et al., 2005a; Almeida et al., 2005b).

Throughout the specification, the term “pharmacoresistant”, and variations thereon, will be understood to relate to a condition where the patient is not responsive to pharmaceutical treatment at all;

the term “refractory” will be understood to relate to a condition wherein the patient becomes progressively less responsive to their medication and, in the case of epilepsy, suffers from an increasing number of seizures; and

the term “intractable”, and variations thereon, will be understood to signify difficult-to-treat or treatment(drug)-resistant and thus encompasses both pharmacoresistant and refractory conditions.

Resistance to pharmacological therapy (pharmacoresistance) is one of the major problems in the treatment of epilepsy (Löscher et al., 2004). Approximately one third of all epilepsy patients do not become seizure free, despite treatment with two or more antiepileptic drugs (AEDs) at a maximal tolerated dose. This intractability is even higher (50–70%) in patients with temporal lobe epilepsy (Kwan et al., 2000; Mohanraj et al., 2005; Schmidt et al., 2005; Stephen et al., 2006). Although the causes and mechanisms underlying pharmacoresistance are not fully understood, drug-efflux transporters of the adenosine triphosphate (ATP)-binding cassette (ABC) family (multidrug transporters) may play an important role. P-glycoprotein (P-gp or ABCB1 or MDR1) is the most extensively studied multidrug transporter. In fact, P-gp transports a variety of xenobiotics, including commonly used AEDs (Potschka et al., 2002; Potschka et al., 2001a; Potschka et al., 2001b; Rizzi et al., 2002; Sills et al., 2002).

In fact, a current popular hypothesis is that overexpression of drug efflux ("multidrug") transporters at the brain capillary endothelium induced by repetitive seizure activities lowers AED concentration in brain interstitial fluid and contributes to drug resistance (Kwan et al., 2005; Löscher et al., 2005a; Löscher et al., 2005b; Schmidt et al., 2005). Several studies have shown that such drug efflux transporters, including P-glycoprotein (P-gp or MDR1) and members of the multidrug resistance protein (MRP) family, are overexpressed in surgically resected brain tissue from patients with medically intractable epilepsy (Kwan et al., 2005; Löscher et al., 2005a; Löscher et al., 2005b; Schmidt et al., 2005). Furthermore, in epileptogenic brain tissue from patients with pharmacoresistant epilepsy, an overexpression of several multidrug transporters, including P-glycoprotein (P-gp) and members of the multidrug resistance protein (MRP) family such as MRP1 and MRP2 has been reported (Aronica et al., 2003; Dombrowski et al., 2001; Sisodiya et al., 2002; Tishler et al., 1995). Overexpression was found both in brain capillary endothelial cells that form the blood–brain barrier (BBB) and in astrocytes and astrocyte processes that ensheath the endothelial cells and contribute to BBB function. In human refractory epileptic brain tissue (Aronica et al., 2003; Aronica et al., 2004; Marchi et al., 2004; Sisodiya et al., 2002; Tishler et al., 1995), as well as in the epileptic rat brain (van Vliet et al., 2004; Volk et al., 2004a; Volk et al., 2004b), P-gp is overexpressed in endothelial cells, neurons, and glial cells. P-gp overexpression, particularly in endothelial cells, may lead to increased extrusion of drugs from the brain to the blood, preventing the attainment

of appropriate AED concentrations at therapeutic targets. Because multidrug transporters such as P-gp and MRPs accept a wide range of drugs as substrates, overexpression of such efflux transporters in the BBB would be one likely explanation for resistance to various AEDs in a patient with intractable epilepsy (Kwan et al., 2005; Löscher et al., 2005a; Löscher et al., 2005b; Schmidt et al., 2005).

The consequences of uncontrolled epilepsy can be severe, and include shortened lifespan, bodily injury, neuropsychological and psychiatric impairment, and social disability (Sperling, 2004). Most patients with refractory epilepsy are resistant to several, if not all, AEDs, despite the fact that these drugs act by different mechanisms (Kwan et al., 2000; Sisodiya, 2003). This multidrug type of resistance argues against epilepsy-induced alterations in specific drug targets as the main cause of pharmacoresistant epilepsy, pointing instead to nonspecific and possibly adaptive mechanisms (Sisodiya, 2003). Epilepsy was the first CNS disorder for which drug resistance was associated with enhanced expression of multidrug transporters in the brain (Tishler et al., 1995). The expression of multidrug transporters in the astroglial end-feet covering the blood vessels that are found in epileptogenic brain tissue might represent a 'second barrier' under these conditions (Abbott, 2002; Sisodiya et al., 2002). Several widely used AEDs, which have been made lipophilic to allow them to penetrate the brain, are substrates for P-gp or MRPs in the BBB (Potschka et al., 2002; Potschka et al., 2001a; Potschka et al., 2003; Potschka et al., 2001b; Rizzi et al., 2002; Schinkel et al., 1996; Sills et al., 2002; Tishler et al., 1995). As a result, the uptake of these drugs by the brain can be increased by knocking out or blocking P-gp. The overexpression of these transporters in epileptogenic tissue is likely, therefore, to reduce the amount of drug that reaches the epileptic neurons. This is one plausible explanation for multidrug resistance in epilepsy (Sisodiya, 2003).

Although the multidrug transporter hypothesis of intractable epilepsy is biologically plausible, it has not been proven (Löscher et al., 2004; Sisodiya, 2003). Despite the fact that high P-gp expression has been shown in epileptogenic brain tissue from patients with intractable epilepsy, adequate controls are lacking, as it is impossible to compare this tissue directly with tissue from patients who respond well to AED treatment (because these patients do not need to undergo surgical resection of epileptogenic foci). Consequently, it is not clear whether the increased P-gp expression in patients with drug-

resistant epilepsy is a cause of pharmacoresistance or just a result of uncontrolled seizures — or an epiphenomenon that occurs in epileptic brain tissue irrespective of drug response. For direct proof-of-principle, it should be established whether P-gp inhibitors counteract multidrug resistance in epilepsy. In line with this suggestion, Summers et al . (Summers et al., 2004) recently reported that combined treatment with verapamil and AEDs greatly improved overall seizure control and subjective quality of life in a patient with intractable epilepsy. Verapamil is a calcium channel blocker that is transported by P-gp and competitively blocks the transport of other substrates by P-gp (Schinkel et al., 2003). Because of its efficient efflux transport by P-gp at the BBB, verapamil itself does not penetrate into the brain (Kortekaas et al., 2005), so the improved seizure control observed both experimentally and clinically in response to co-administration of verapamil and AEDs is not secondary to the calcium channel-blocking effect of verapamil. Following the promising clinical results of combined treatment with verapamil and AEDs (Summers et al., 2004), Summers et al. went on to test combinations of AEDs and verapamil in other patients with drug-resistant epilepsy, again with a favourable outcome (for details see (Löscher et al., 2005a)).

Oxcarbazepine has been used either in monotherapy or in adjunctive therapy in patients with partial-onset seizures with or without secondary generalization (May et al., 2003; Schmidt et al., 2001; Shorvon, 2000; Tartara et al., 1993). Oxcarbazepine undergoes rapid 10-keto reduction to a mixture of S-licarbazepine and R-licarbazepine the racemic mixture if which is usually referred as licarbazepine (10-hydroxy-10,11-dihydrocarbazepine, 10-OHCBZ, or MHD) (Faigle et al., 1990; Feldmann et al., 1978; Feldmann et al., 1981; Flesch et al., 1992; Schutz et al., 1986; Volosov et al., 1999).

Recently, licarbazepine (10-OHCBZ) was suggested not to cross the blood–brain barrier by simple diffusion, namely being a substrate of P-gp. In fact, the level of expression of MDR1 was found to be inversely correlated with 10-OHCBZ concentration in the epileptic tissue (Marchi et al., 2005). It was concluded that P-gp may play a role in the resistance to oxcarbazepine by determining the attainment of insufficient concentrations of its active metabolite at neuronal targets (Marchi et al., 2005). In the rat, which does not convert oxcarbazepine to licarbazepine (10-OHCBZ), co-administration of the P-gp inhibitor verapamil significantly potentiated the anticonvulsant activity of oxcarbazepine

in the pilocarpine seizure model (Clinckers et al., 2005). However, it remains to be determined whether P-gp or MRPs are endowed with identical affinity for S-licarbazepine and R-licarbazepine.

We have now unexpectedly discovered that S-licarbazepine is not a substrate for P-glycoprotein (P-gp) or Multiple Resistant Proteins (MRPs). This discovery offers opportunities for the treatment of pharmacoresistant epilepsy, and other conditions.

We have also unexpectedly discovered an enhanced brain exposure to S-licarbazepine versus that conferred by R-licarbazepine. The enhanced brain penetration of S-licarbazepine correlated positively with the enhanced efficacy of S-licarbazepine versus R-licarbazepine in experimental models of epileptogenesis (corneal kindling) and pain.

We have also unexpectedly discovered that inhibitors of P-gp or MRPs do not interfere with the brain penetration of the main active metabolite of eslicarbazepine acetate, S-licarbazepine, a discovery that offers opportunities for the treatment of pharmacoresistant epilepsy with eslicarbazepine acetate.

Due to the unexpected potential of eslicarbazepine, the main active metabolite of eslicarbazepine acetate, to not serve as a substrate for efflux pumps such as P-gp and MRP, and therefore not require adjunctive administration of a P-gp or MRP inhibitor these compounds are considered to offer advantages over other AEDs for the clinical management of difficult-to-treat patients afflicted with epilepsy, central and peripheric nervous system disorders, affective disorders, schizoaffective disorders, bipolar disorders, attention disorders, anxiety disorders, neuropathic pain and neuropathic pain-related disorders, sensorimotor disorders, vestibular disorders, and nervous function alterations in degenerative and post-ischemic diseases.

According to one aspect of the invention there is provided the use of eslicarbazepine or eslicarbazepine acetate in the manufacture of a medicament for treating a condition selected from epilepsy, central and peripheric nervous system disorders, affective disorders, schizoaffective disorders, bipolar disorders, attention disorders, anxiety disorders, neuropathic pain and neuropathic pain-related disorders, sensorimotor

disorders, vestibular disorders, and nervous function alterations in degenerative and post-ischemic diseases in circumstances where the use of a P-glycoprotein inhibitor or a Multiple Resistant Protein inhibitor would adversely affect the subject being treated.

For example, the administration of the P-glycoprotein inhibitor, verapamil, adversely affects subjects suffering from a heart condition. Thus, the administration of eslicarbazepine or eslicarbazepine acetate to a patient suffering from a heart condition, and who is also suffering from one or more of said selected conditions mentioned above, enables the selected condition or conditions to be treated effectively without the need for administering a P-glycoprotein inhibitor or a Multiple Resistant Protein inhibitor.

Examples of heart conditions which are adversely affected by the administration of verapamil include: Bradycardia; second and third degree atrioventricular block; heart failure; Wolff-Parkinson-White syndrome; patients using beta-blocker treatment.

Contra-indications for cyclosporine include but are not limited to: patients hypersensitive to cyclosporine, uncontrolled hypertension, premalignant skin lesions or current malignancies, chickenpox and herpes zoster, renal or hepatic impairment, patients suffering from any type of bacterial or viral infection.

Contra-indications for probenecid include but are not limited to: hypersensitivity to probenecid or colchicine, patients under 2 years of age, blood dyscrasias, uric acid kidney stones.

Thus, the administration of eslicarbazepine or eslicarbazepine acetate to a patient suffering from one of the contra-indicated conditions or falling into one of the contra-indicated categories listed above, and who is also suffering from one or more of epilepsy, central and peripheric nervous system disorders, affective disorders, schizoaffective disorders, bipolar disorders, attention disorders, anxiety disorders, neuropathic pain and neuropathic pain-related disorders, sensorimotor disorders, vestibular disorders, and nervous function alterations in degenerative and post-ischemic diseases, enables this latter condition or conditions to be treated effectively without the need for administering a P-glycoprotein inhibitor or a Multiple Resistant Protein inhibitor.

According to a further aspect of the invention there is provided the use of eslicarbazepine acetate or eslicarbazepine in the manufacture of a medicament for treating a drug resistant condition selected from epilepsy, central and peripheric nervous system disorders, affective disorders, schizoaffective disorders, bipolar disorders, attention disorders, anxiety disorders, neuropathic pain and neuropathic pain-related disorders, sensorimotor disorders, vestibular disorders, and nervous function alterations in degenerative and post-ischemic diseases, wherein the patient to be treated is suffering from a condition which requires administration of a drug which reacts adversely with a P-gp inhibitor or an MRP inhibitor.

Examples of P-glycoprotein inhibitors and Multiple Resistant Protein inhibitors include: cyclosporin, verapamil, valspodar, biricodar, probenecid, elacridar, tariquidar XR9576, zosuquidar LY335979, laniquidar R101933, ONT-093.

According to another aspect of the invention there is provided the use of eslicarbazepine or eslicarbazepine acetate in the manufacture of a medicament for treating an intractable condition selected from epilepsy, central and peripheric nervous system disorders, affective disorders, schizoaffective disorders, bipolar disorders, attention disorders, anxiety disorders, neuropathic pain and neuropathic pain-related disorders, sensorimotor disorders, vestibular disorders, and nervous function alterations in degenerative and post-ischemic diseases.

Preferably the intractable condition is, at least in part, caused by an overexpression of P-gp or MRP.

Preferably the intractable state of the condition is, at least in part, due to an overexpression of P-gp or MRP.

Preferably the intractable condition is a pharmacoresistant condition.

In an alternative embodiment, the intractable state of the condition is due to the patient's being resistant to treatment with a pharmaceutical which is not a substrate for P-gp or MRP.

Preferably the intractable condition is a pharmacoresistant condition.

In the above aspects of the invention, preferably the eslicarbazepine or eslicarbazepine acetate is administered as a monotherapy for treating said condition. Preferably the eslicarbazepine or eslicarbazepine acetate is administered in the absence of a P-glycoprotein inhibitor, such as verapamil, or a Multiple Resistant Protein inhibitor, such as probenecid.

According to another aspect of the invention there is provided the use of eslicarbazepine or eslicarbazepine acetate, in combination with a second drug which reacts adversely with a P-glycoprotein inhibitor or a Multiple Resistant Protein inhibitor, in the manufacture of a medicament for treating a condition selected from epilepsy, central and peripheric nervous system disorders, affective disorders, schizoaffective disorders, bipolar disorders, attention disorders, anxiety disorders, neuropathic pain and neuropathic pain-related disorders, sensorimotor disorders, vestibular disorders, and nervous function alterations in degenerative and post-ischemic diseases.

The second drug may be a drug for the treatment of bradycardia; second and third degree atrioventricular block; heart failure; or Wolff-Parkinson-White syndrome; uncontrolled hypertension; premalignant skin lesions or current malignancies; chickenpox or herpes zoster; renal or hepatic impairment; any type of bacterial or viral infection; blood dyscrasias; or uric acid kidney stones.

The condition may be an intractable condition.

Preferably the intractable condition is, at least in part, caused by an overexpression of P-gp or MRP.

Preferably the intractable state of the condition is, at least in part, due to an overexpression of P-gp or MRP.

Preferably the intractable condition is a pharmacoresistant condition.

Preferably the intractable condition is a refractory condition.

In an alternative embodiment, the intractable state of the condition is due to the patient's being resistant to treatment with a pharmaceutical which is not a substrate for P-gp or MRP.

Preferably the intractable condition is a pharmacoresistant condition.

Preferably the intractable condition is a refractory condition.

Preferably the eslicarbazepine or eslicarbazepine acetate and the second drug are administered in the absence of a P-glycoprotein inhibitor, such as verapamil, or a Multiple Resistant Protein inhibitor, such as probenecid.

According to another aspect of the invention there is provided the use of eslicarbazepine or eslicarbazepine acetate, in combination with a drug to treat a heart condition, in the manufacture of a medicament for treating said heart condition and a further condition selected from epilepsy, central and peripheric nervous system disorders, affective disorders, schizoaffective disorders, bipolar disorders, attention disorders, anxiety disorders, neuropathic pain and neuropathic pain-related disorders, sensorimotor disorders, vestibular disorders, and nervous function alterations in degenerative and post-ischemic diseases.

The drug for treating the heart conditions may be a drug for the treatment of bradycardia; second and third degree atrioventricular block; heart failure; or Wolff-Parkinson-White syndrome.

According to another aspect of the invention there is provided the use of eslicarbazepine or eslicarbazepine acetate, in combination with a drug to treat one or more of the following conditions: uncontrolled hypertension, premalignant skin lesions or current malignancies, chickenpox and herpes zoster, renal or hepatic impairment, any type of bacterial/viral infection, blood dyscrasias, and uric acid kidney stones, in the manufacture of a medicament for treating said condition and a further condition

selected from epilepsy, central and peripheric nervous system disorders, affective disorders, schizoaffective disorders, bipolar disorders, attention disorders, anxiety disorders, neuropathic pain and neuropathic pain-related disorders, sensorimotor disorders, vestibular disorders, and nervous function alterations in degenerative and post-ischemic diseases.

The epilepsy, central and peripheric nervous system disorders, affective disorders, schizoaffective disorders, bipolar disorders, attention disorders, anxiety disorders, neuropathic pain and neuropathic pain-related disorders, sensorimotor disorders, vestibular disorders, and nervous function alterations in degenerative and post-ischemic diseases may be intractable, which intractable state may be caused by overexpression of P-gp and/or MRP.

Preferably the intractable condition is a pharmacoresistant condition.

Preferably the intractable condition is a refractory condition.

In an alternative embodiment, the intractable state of the condition is due to the patient's being resistant to treatment with a pharmaceutical which is not a substrate for P-gp or MRP.

Preferably the intractable condition is a pharmacoresistant condition.

Preferably the intractable condition is a refractory condition.

According to another aspect of the invention, there is provided a pharmaceutical composition comprising eslicarbazepine acetate or eslicarbazepine in combination with a drug which reacts adversely with a P-glycoprotein inhibitor or a Multiple Resistant Protein inhibitor, and a pharmaceutically acceptable carrier.

The drug which reacts adversely with a P-glycoprotein inhibitor or a Multiple Resistant Protein inhibitor may be a drug for the treatment of bradycardia; second and third degree atrioventricular block; heart failure; or Wolff-Parkinson-White syndrome; uncontrolled

hypertension, premalignant skin lesions or current malignancies, chickenpox and herpes zoster, renal or hepatic impairment, any type of bacterial/viral infection, blood dyscrasias, and uric acid kidney stones.

According to another aspect of the invention, there is provided a pharmaceutical composition comprising eslicarbazepine acetate or eslicarbazepine in combination with a drug for treating one or more of the following conditions: a heart condition, uncontrolled hypertension, premalignant skin lesions or current malignancies, chickenpox and herpes zoster, renal or hepatic impairment, any type of bacterial/viral infection, blood dyscrasias, and uric acid kidney stones, and a pharmaceutically acceptable carrier.

The drug for treating the heart condition may be a drug for the treatment of bradycardia; second and third degree atrioventricular block; heart failure; or Wolff-Parkinson-White syndrome.

The pharmaceutical composition may be formulated in any suitable manner, such as an oral dosage form, such as a tablet or capsule.

It will be appreciated from the foregoing that in accordance with the invention eslicarbazepine or eslicarbazepine acetate may be used to treat a variety of conditions which have previously proved difficult to treat with medicaments that are substrates for P-glycoprotein or Multiple Resistant Proteins.

As used herein, the term treatment and variations such as 'treat' or 'treating' refer to any regime that can benefit a human or non-human animal. The treatment may be in respect of an existing condition or may be prophylactic (preventative treatment). Treatment may include curative, alleviation or prophylactic effects.

In particular, eslicarbazepine and eslicarbazepine acetate are useful to treat patients who suffer from a relapse after treatment with one or more pharmaceutical, i.e. refractory conditions, and also those who are unresponsive to treatment with any pharmaceutical, i.e. pharmacoresistant conditions.

In epilepsy, for example, eslicarbazepine and eslicarbazepine acetate would be useful in the treatment of subjects having more than 4 seizures per week despite with treatment with one or more antiepileptic drug.

In affective disorders such as mania, eslicarbazepine and eslicarbazepine acetate would be useful in the treatment of subjects suffering from a relapse after administration of one or more pharmaceutical which is a P-gp or MRP transporter substrate (e.g. carbamazepine, oxcarbazepine).

In neuropathic pain disorders, eslicarbazepine and eslicarbazepine acetate would be useful in the treatment of subjects suffering from a relapse after administration of one or more analgesic which is P-gp or MRP transporter substrate (e.g. carbamazepine, oxcarbazepine).

It will be appreciated that the invention also encompasses methods of treating the conditions mentioned above, which involve administering a therapeutically effective amount of the active ingredient or ingredients to a subject in need thereof.

The subject treated in accordance with the invention is preferably a human subject.

Medical conditions that can be treated with either eslicarbazepine acetate or S-licarbarzepine with no need for adjunctive therapy with P-gp or MRP blockers include:

1. Affective disorders
2. Schizoaffective disorders
3. Bipolar disorders
4. Attention disorders
5. Anxiety disorders
6. Neuropathic pain and neuropathic pain related disorders
7. Sensorimotor disorders
8. Vestibular disorders

1. Affective disorders include:

Depression, pre-menstrual dysphoric disorder, post partum depression, post-menopausal depression, anorexia nervosa, bulimia nervosa, and neurodegeneration-related depressive symptoms.

2. Schizoaffective disorders include:

Schizodepressive syndromes, schizophrenia, extreme psychotic states, schizomanic syndromes, dysphoric and aggressive behavior, episodic dyscontrol or intermittent explosive disorder, and borderline personality disorder.

3. Bipolar disorders include:

Bipolar disorder and unstable bipolar disorder with rapid fluctuations (rapid cyclers), manic-depressive disorders, acute mania, mood episodes, and manic and hypomanic episodes.

4. Attention disorders include:

Attention deficit hyperactivity disorders and other attention disorders such as autism.

5. Anxiety disorders include:

Social anxiety disorders, post traumatic stress disorder, panic, obsessive compulsive disorder, alcoholism, drug withdrawal syndromes and craving.

6. Neuropathic pain and neuropathic pain related disorders include:

Neuropathic pain and associated hyperalgesia, including trigeminal, herpetic post-herpetic and tabetic neuralgia, diabetic neuropathic pain, migraine, tension-type headache, causalgia, and deafferentation syndromes such as brachial plexus avulsion.

7. Sensorimotor and related disorders disorders include:

Restless legs syndrome, spasticity, hemifacial spasm, nocturnal paroxysmal dystonia, brain ischemia associated motor and sensitive deficits, Parkinson's disease and parkinsonian disorders, antipsychotic-induced motor deficits, tardive dyskinesia, episodic nocturnal wandering and myotonia.

8. Vestibular disorders include:

Tinnitus or other inner ear/cochlear excitability related diseases, including neuronal loss, hearing loss, sudden deafness, vertigo or Meniere's disease.

Reference is made to the accompanying drawings, in which:

Figure 1 is a graph showing the brain/plasma ratio (Cmax and AUC) for S-licarbazepine and R-licarbazepine;

Figure 2 shows the effect of probenecid and verapimil on the brain plasma ratio for S-licarbazepine and R-licarbazepine;

Figure 3 shows the effect of verapamil and probenecid on the the S-licarbazepine brain/plasma ratio after the administration eslicarbazepine acetate;

Figure 4 shows the effect of twice daily treatment with S-licarbazepine on acquisition of kindling;

Figure 5 shows the effect of twice daily treatment with R-licarbazepine on acquisition of kindling; and

Figure 6 shows formalin paw test data for S-licarbazepine, R-licarbazepine and gabapentin.

Methods and materials

Brain access of S-licarbazepine and R-licarbazepine

CD-1 mice weighing 30-35 g were maintained under controlled environmental conditions (23-24 °C) for at least 5 days before the experiment. All animals interventions were performed in accordance with the European Directive number 86/609, and the rules of the "Guide for the Care and Use of Laboratory Animals", 7th edition, 1996, Institute for Laboratory Animal Research (ILAR), Washington, DC. In the first series of experiments mice were given by gastric tube S-licarbazepine or R-licarbazepine (350 mg/kg). Blood and brain samples were obtained at 12 different timepoints (15min, 30min, 45min, 1h, 2h, 4h, 6h, 10h, 16h, 24h, 48h and 72h) after drug administration. In the second series of experiments, mice pre-treated with vehicle, verapamil (20 mg/kg) or probenecid (100 mg/kg) were given 30 min later intraperitoneally S-licarbazepine or R-licarbazepine (100 mg/kg). Probenecid has been shown to inhibit both MRP1 and MRP2 (Gerk et al., 2002; Scheffer et al., 2002), but also inhibits organic anion transporters. Although more selective P-gp and MRP1/2 inhibitors exist, verapamil and probenecid are widely used standard inhibitors of these multidrug transporters. After collection of blood, plasma was obtained by centrifugation. Brain samples were homogenised in phosphate buffer (pH 5; 4mL/g) followed by centrifugation and collection of the supernatant. Plasma and the tissue supernatant were stored frozen until analysis. The assay of S-licarbazepine and R-licarbazepine was performed using a HPLC-UV or LC-MS method following solid phase extraction.

The following pharmacokinetic parameters for S-licarbazepine and R-licarbazepine were derived by non-compartmental analysis from the concentration versus time profiles: maximum observed plasma drug concentration (Cmax), time at which the Cmax occurred (tmax), area under the plasma concentration versus time curve (AUC) from time zero to the last sampling time at which concentrations were at or above the limit of quantification

(AUC0-t) and AUC from time zero to infinity (AUC0-∞), elimination half-life (t1/2) and mean residence time (MRT). The pharmacokinetic parameters were determined using WinNonlin (version 4.0). Summary statistics of all data for each treatment and scheduled sampling times were reported, as appropriate, using the geometric mean, arithmetic mean, standard deviation (SD), coefficient of variation (CV), median, minimum and maximum. The statistical package SAS Version 8.2 or higher (SAS Institute, Cary, USA) was used in all computations when considered appropriate.

Kindling procedure

Vehicle (30% DMSO in distilled water) or the compounds dissolved in 30% DMSO were administered intraperitoneally twice daily. NMRI mice were stimulated twice daily (interstimulation interval 6-7 h) on twelve consecutive days. The electrostimulations with current intensities of 3 mA and duration of 3 s (pulse frequency 50 Hz) were applied via corneally placed saline-soaked copper electrodes. A stimulator was used to deliver a constant current regardless of the impedance of the test object. Seizure severity was ranked according to a modified system of Racine (Racine, 1972): 1, mild facial clonus and eye blinking; 2, severe facial clonus, head nodding, chewing; 3, unilateral or alternating forelimb clonus; 4, bilateral forelimb clonus with rearing and falling; 5, bilateral forelimb clonus with rearing and falling; 6, tonic fore- and/or hindlimb extension.

Formalin paw test

The method, which detects analgesic/anti-inflammatory activity, follows that described by Wheeler-Aceto et al (Wheeler-Aceto et al., 1991). NMRI mice were given an intraplantar injection of 5% formalin (25 µl) into the posterior left paw. This treatment induced paw licking in control animals. The time spent licking was counted for 15 minutes, beginning 15 minutes after injection of formalin. 10 mice were studied per group. The test was performed blind. S-Licarbazepine and R-licarbazepine were tested at the dose of 100 mg/kg p.o., administered 120 minutes before the test (i.e. 100 minutes before formalin), and compared with a vehicle control group in each experiment.

Results

Brain access of S-licarbazepine and R-licarbazepine

As depicted in Table 1, both S-licarbazepine and R-licarbazepine are rapidly absorbed after oral administration with Cmax in plasma attained at 15 min (tmax). After the administration of S-licarbazepine only S-licarbazepine is found in plasma, whereas after the administration of R-licarbazepine small amounts of S-licarbazepine were found to be detectable in plasma though the major circulating material is R-licarbazepine (Table 1). Though there are differences in the plasma profiles between S-licarbazepine and R-licarbazepine, it is quite clear that there are similarities for both enantiomers in what concerns their systemic exposure (AUCplasma(S-Licarbazepine)/AUCplasma(R-Licarbazepine) = 1.1), elimination half-life (t1/2 ≈ 8h) and mean residence time (MRT ≈ 10-12h).

In brain, after the administration of S-licarbazepine and R-licarbazepine, the presence respectively of R-licarbazepine and S-licarbazepine is almost negligible (Table 2). This is in line with that observed in plasma. As it would be expected, a comparison of the plasma PK profiles and the brain PK profiles indicates a rightward shift of the brain PK profiles (from 0.25 h to 1.00 h for S-Licarbazepine; from 0.25 h to 0.75 h for R-licarbazepine).

A comparison of the data following the administration of S-licarbazepine with that of R-licarbazepine indicates that the brain ratio AUCbrain(S-Licarbazepine)/AUCbrain(R-Licarbazepine) is 1.9 is greater than that in plasma (AUCplasma(S-Licarbazepine)/AUCplasma(R-Licarbazepine) =1.1). Thus, it is suggested that distribution of S-licarbazepine into the brain is more favourable than that (almost twice) for R-licarbazepine. However, when other parameters such as half-life and MRT are considered it is apparent that R-Licarbazepine has considerable more difficulty in entry the brain. In fact, as can be observed in figure 1, the brain/plasma ratio (considering either Cmax or AUC), the S-licarbazepine brain/plasma ratio was considerably greater than the R-licarbazepine brain/plasma. This clearly indicates that there is stereoselectivity in the process of crossing the blood-brain barrier.

To assess whether differences in brain penetration of S-licarbazepine and R-licarbazepine were related to susceptibility for efflux through P-gp or MRP, mice were pretreated with verapamil or probenecid. As shown, in figure 2, verapamil and probenecid failed to affect the S-licarbazepine brain/plasma ratio. By contrast, verapamil, but not probenecid, markedly increased the R-licarbazepine brain/plasma ratio (figure 2). This indicates that S-licarbazepine is not a substrate for both P-gp and MRP, whereas R-licarbazepine is a substrate for P-gp, but not for MRP. It is interesting to underline the fact that the R-licarbazepine brain/plasma ratio after verapamil equals that of S-licarbazepine in vehicle-treated animals (figure 2).

As shown, in figure 3, verapamil and probenecid failed to affect the S-licarbazepine brain/plasma ratio after the administration eslicarbazepine acetate (100 mg/kg, i.p.).

Acquisition of kindling

Effect of S-Licarbazepine

Twice daily treatment with S-licarbazepine 100 mg/kg exhibited an inhibitory effect on acquisition of kindling (figure 4). As compared to the vehicle control group mean seizure severity proved to be significantly lower in the 100 mg/kg S-licarbazepine treatment group at all stimulation sessions of the first three days. The number of stimulations necessary to induce a seizure with a severity score of 3 and 4 was significantly increased in mice that received administrations of S-licarbazepine 100 mg/kg (figure 4). When treatment was terminated at day 12 100% of the vehicle-treated animals and all of the treated animals had reached the kindling criterion, i.e. at least one generalized seizure (score 4-6). During the course of the experiment no adverse effects were obvious in S-licarbazepine treated animals.

Effect of R-licarbazepine

Twice daily treatment with R-licarbazepine 100 mg/kg exhibited no inhibitory effect on acquisition of kindling (figure 5). When seizure severity scores were compared between R-licarbazepine treated animals and control animals, no significant differences were determined except for one stimulation session, i.e. the stimulation in the afternoon of day 8. The number of stimulations necessary to induce a seizure with a severity score of 3, 4, 5, and 6 did not differ between treated mice and control mice (figure 5). When treatment was terminated at day 12 100% of the vehicle-treated animals and all of the treated animals had reached the kindling criterion, i.e. at least one generalized seizure (score 4-6). During the course of the experiment no adverse effects were obvious in R-licarbazepine treated animals.

Formalin paw test

As shown in figure 6, S-licarbazepine at 100 mg/kg, administered p.o. 120 minutes before the test (i.e. 100 minutes before formalin), significantly decreased the licking time, as compared with vehicle controls. The decrease in licking time after the administration of R-licarbazepine (100 mg/kg, p.o.) 120 minutes before the test (i.e. 100 minutes before formalin), did not attain statiscal significance, as compared with vehicle controls. Gabapentin (100 mg/kg, p.o.), administered 120 minutes before the test (i.e. 100 minutes before formalin) significantly ($p < 0.05$) decreased the licking time, as compared with vehicle controls.

Tables

Table 1. Plasma pharmacokinetic (PK) parameters for S-licarbazepine and R-licarbazepine after the oral administration of 350 mg/kg S-licarbazepine or 350 mg/kg R-licarbazepine to CD-1 mice.

Plasma PK Parameters	after S-Licarbazepine		after R-Licarbazepine	
	S-Lic	R-Lic	S-Lic	R-Lic
tmax (h)	0.25	NC	0.25	0.25
Cmax (ng/mL)	41304	NC	1024	69946
AUC0-t (ng.h/mL)	186669	NC	4582	203705
AUC0-∞ (ng.h/mL)	258278	NC	NC	231716
t1/2 (h)	7.93	NC	NC	8.11
MRT (h)	11.71	NC	NC	10.12

NC = not calculated due to absence of measurable concentrations of the analyte.

Table 2. Brain pharmacokinetic (PK) parameters for S-licarbazepine and R-licarbazepine after the oral administration of 350 mg/kg S-licarbazepine or 350 mg/kg R-licarbazepine to CD-1 mice.

Brain PK Parameters	after S-Licarbazepine		after R-Licarbazepine	
	S-Lic	R-Lic	S-Lic	R-Lic
tmax (h)	1.00	NC	NC	0.75
Cmax (ng/mL)	12308	NC	NC	8533
AUC0-t (ng.h/mL)	108610	NC	NC	51516
AUC0-∞ (ng.h/mL)	111302	NC	NC	60037
t1/2 (h)	4.87	NC	NC	7.91
MRT (h)	7.84	NC	NC	11.34

NC = not calculated due to absence of measurable concentrations of the analyte.

Discussion

AEDs that fall into the category of P-gp or MRP substrates include all major voltage-gated sodium channel blockers that are the mainstay treatment of monotherapy and adjunctive therapy of patients afflicted with epilepsy, such as phenytoin, phenobarbital, carbamazepine, oxcarbazepine, felbamate and lamotrigine. Levetiracetam is an exception that has been reported not to be a substrate for either P-gp or MRP1/2, as suggested by the finding that neither inhibition of P-gp nor MRP1/MRP2 by verapamil and probenecid, respectively, increased the brain penetration of levetiracetam.

In a recent clinical study in 120 patients with drug-resistant epilepsy who had tried at least 3–4 other AEDs before levetiracetam was instituted, 32% of the patients were seizure-free six months after initiation of levetiracetam therapy (Betts et al., 2003). This impressive and sustainable seizure freedom rate in difficult-to-treat patients under treatment with levetiracetam has been suggested be either a result of a novel mechanism of action as well as the lack of multidrug transporters to limit brain uptake of levetiracetam as suggested by (Potschka et al., 2004).

Eslicarbazepine acetate, administered once-daily, was demonstrated to be very efficacious in partial epilepsy refractory patients (Maia et al., 2004), a characteristic that may relate to the preferential metabolism into S-licarbazepine, escaping drug efflux transporters, such as P-gp and MRP. It should be underlined that approximately 25% became seizure free 1 month after initiation of eslicarbazepine acetate therapy (Almeida et al., 2007).

Advantages of the use of P-gp and/or MRP inhibitors to overcome drug resistance and facilitate access to organs and cells that express high levels of these transporters is still a matter of debate. Though inhibition of P-gp and/or MRP may facilitate drug transfer of P-gp and MRP substrates, it may also compromise safety, since these transport restrict to a major extent the access to a wide range of xenobiotics, some of which are endowed with considerable unwanted effects (Schinkel et al., 2003; Schinkel et al., 1996). Therefore, it is of considerable advantage to use drugs such as eslicarbazepine acetate and S-licarbazepine, which are not substrate for P-gp and/or MRP, rather than use drugs that transported through transporters, such as R-licarbazepine, phenytoin, phenobarbital,

carbamazepine, oxcarbazepine, felbamate and lamotrigine, in combination with P-gp and/or MRP inhibitors.

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CLAIMS:

1. The use of eslicarbazepine or eslicarbazepine acetate in the manufacture of a medicament for treating a condition selected from epilepsy; central and peripheric nervous system disorders; affective disorders; schizoaffective disorders; bipolar disorders; attention disorders; anxiety disorders; neuropathic pain and neuropathic pain-related disorders; sensorimotor disorders; vestibular disorders; and nervous function alterations in degenerative and post-ischemic diseases; in circumstances where the patient to be treated is refractory to a pharmaceutical which is a substrate for P-glycoprotein.

2. The use according to claim 1, wherein the subject is suffering from one or more of the following conditions: a heart condition, uncontrolled hypertension, premalignant skin lesions or malignancies, chickenpox and herpes zoster, renal or hepatic impairment, any type of bacterial/viral infection, blood dyscrasias, and uric acid kidney stones.

3. The use according to claim 1, wherein the condition is epilepsy.

4. The use according to claim 1 or 2, wherein the subject is hypersensitive to one or more of the following: cyclosporine, verapamil, colchine, valspodar, biricodar, probenecid, elacridar, tariquidar XR9576, zosuquidar LY335979, laniquidar R101933, or ONT-093.

5. The use according to any of claims 1 to 3, wherein the subject is under 2 years of age.

6. The use according to any one of the preceding claims, wherein the pharmaceutical which is a substrate for P-glycoprotein is phenytoin, phenobarbital, carbamazepine, oxcarbazepine, felbamate or lamotrigine.

7. The use according to any one of the preceding claims, wherein the eslicarbazepine or eslicarbazepine acetate is administered as a monotherapy for treating said condition.

8. The use according to any one of the preceding claims, wherein the eslicarbazepine or eslicarbazepine acetate is administered in the absence of a P-glycoprotein inhibitor or a Multiple Resistant Protein inhibitor.

9. The use according to any of claims 7 to 8 wherein the refractory state of the condition is due to overexpression of P-gp and/or MRP.

10. The use of eslicarbazepine or eslicarbazepine acetate, in combination with a second drug which reacts adversely with a P-glycoprotein inhibitor or a Multiple Resistant Protein inhibitor, in the manufacture of a medicament for treating a condition selected from epilepsy; central and peripheric nervous system disorders; affective disorders; schizoaffective disorders; bipolar disorders; attention disorders; anxiety disorders; neuropathic pain and neuropathic pain-related disorders; sensorimotor disorders; vestibular disorders; and nervous function alterations in degenerative and post-ischemic diseases; in circumstances where the patient to be treated is refractory to a pharmaceutical which is a substrate for P-glycoprotein.

11. The use according to claim 10 wherein the refractory state of the condition is due to overexpression of P-gp and/or MRP.

12. The use according to any of claims 10 to 11, wherein said medicament does not include a P-glycoprotein inhibitor or a Multiple Resistant Protein inhibitor.

13. The use of eslicarbazepine or eslicarbazepine acetate, in combination with a drug to treat a heart condition, in the manufacture of a medicament for treating said heart condition and a further condition selected from epilepsy, central and peripheric nervous system disorders, affective disorders, schizoaffective disorders, bipolar disorders, attention disorders, anxiety disorders, neuropathic pain and neuropathic pain-related disorders, sensorimotor disorders, vestibular disorders, and nervous function alterations in degenerative and post-ischemic diseases.

14. The use of eslicarbazepine or eslicarbazepine acetate, in combination with a drug to treat a one or more of the following conditions: uncontrolled hypertension, premalignant skin lesions or malignancies, chickenpox and herpes zoster, renal or hepatic impairment, any type of bacterial or viral infection, blood dyscrasias, and uric acid kidney stones, in the manufacture of a medicament for treating said condition and a further condition selected

from epilepsy, central and peripheric nervous system disorders, affective disorders, schizoaffective disorders, bipolar disorders, attention disorders, anxiety disorders, neuropathic pain and neuropathic pain-related disorders, sensorimotor disorders, vestibular disorders, and nervous function alterations in degenerative and post-ischemic diseases.

15. The use according to claim 13 or 14, wherein the condition selected from epilepsy, central and peripheric nervous system disorders, affective disorders, schizoaffective disorders, bipolar disorders, attention disorders, anxiety disorders, neuropathic pain and neuropathic pain-related disorders, sensorimotor disorders, vestibular disorders, and nervous function alterations in degenerative and post-ischemic diseases is intractable.

16. The use according to claim 15, wherein the intractable state of the condition is due to over-expression of P-gp and/or MRP.

17. The use according to claim 15 or claim 16, wherein the intractable condition is a pharmacoresistant condition.

18. The use according to claim 15 or claim 16, wherein the intractable condition is a refractory condition.

19. The use according to claim 13 or 14, in circumstances where the patient to be treated is refractory to a pharmaceutical which is a substrate for P-glycoprotein.

20. A pharmaceutial composition comprising eslicarbazepine acetate or eslicarbazepine in combination with a drug which reacts adversely with a P-gp inhibitor or an MRP inhibitor, and pharmaceutically acceptable carrier, wherein the drug is for treating one or more of the following conditions: a heart condition, uncontrolled hypertension, premalignant skin lesions or malignancies, chickenpox and herpes zoster, renal or hepatic impairment, any type of bacterial or viral infection, blood dyscrasias, and uric acid kidney stones.

21. A pharmaceutical composition comprising eslicarbazepine acetate or eslicarbazepine in combination with a drug for treating a one or more of the following conditions: a heart

condition, uncontrolled hypertension, premalignant skin lesions or malignancies, chickenpox and herpes zoster, renal or hepatic impairment, any type of bacterial or viral infection, blood dyscrasias, and uric acid kidney stones, and a pharmaceutically acceptable carrier.

22. A pharmaceutical composition according to claim 20 or 21, for administration in circumstances where the patient is refractory to a pharmaceutical which is a substrate for P-glycoprotein.