

AUSTRALIAN PRODUCT INFORMATION – HOSPIRA™ LEVETIRACETAM (LEVETIRACETAM) CONCENTRATE FOR IV INFUSION

1. NAME OF THE MEDICINE

Levetiracetam

2. QUALITATIVE AND QUANTITATIVE COMPOSITION

Hospira Levetiracetam concentrate for IV infusion contains 500 mg of levetiracetam in 5 mL.

For the full list of excipients, see Section 6.1 List of excipients.

3. PHARMACEUTICAL FORM

Concentrated injection for intravenous infusion.

Hospira Levetiracetam concentrate for IV infusion is a clear, colourless and sterile aqueous solution.

4. CLINICAL PARTICULARS

4.1 Therapeutic indications

Hospira Levetiracetam concentrate for IV infusion after dilution is an alternative for patients when oral administration is temporarily not feasible.

Levetiracetam is indicated for:

- use in epileptic patients aged 4 years and older, initially as add-on therapy, in the treatment of partial onset seizures with or without secondary generalisation,
- monotherapy in the treatment of partial onset seizures, with or without secondary generalisation, in patients from 16 years of age with newly diagnosed epilepsy.
- add-on therapy in the treatment of myoclonic seizures in adults and adolescents from 12 years of age with Juvenile Myoclonic Epilepsy, and
- add-on therapy in the treatment of primary generalised tonic-clonic seizures in adults and children from 4 years of age with idiopathic generalised epilepsy.

4.2 Dose and method of administration

Dosage

Levetiracetam therapy can be initiated with either intravenous or oral administration (oral dosage forms including tablets and oral solution are available as other registered products).

Conversion to or from oral to intravenous can be done directly without titration. The total daily dose and frequency of administration should be maintained.

Hospira Levetiracetam concentrate for IV infusion is for intravenous use only and must be diluted in at least 100 mL of a compatible diluent and administered as a 15-minute intravenous infusion (see section 4.2 Dose and method of administration: Instructions for use and handling).

Monotherapy

The recommended starting dose is 250 mg twice daily which should be increased to an initial therapeutic dose of 500 mg twice daily after 2 weeks. The dose can be further increased by 250 mg twice daily every two weeks depending upon the clinical response. The maximum dose is 1500 mg twice daily.

Add-on therapy

Adults (≥18 years of age) and adolescents (aged 12-17 years of age) weighing 50 kg or more

As adjunctive therapy, the therapeutic dose is 500 mg twice daily. This dose can be started on the first day of treatment.

Depending upon the clinical response and tolerance, the daily dose can be increased up to 1500 mg twice daily. Dose changes can be made in 500 mg twice daily increments or decrements every 2 to 4 weeks.

When satisfactory control of seizures has been attained, monotherapy with levetiracetam may be envisaged by progressively decreasing and withdrawing the concomitant antiepileptic medication.

Discontinuation

If levetiracetam has to be discontinued, it is recommended to withdraw it gradually.

Dosage adjustment

Elderly (65 years and older)

Adjustment of the dose is recommended in the elderly with compromised renal function (refer to “Patients with renal impairment” below).

Children (aged 4 to 11 years of age) and adolescents (aged 12-17 years of age) weighing less than 50 kg

The initial therapeutic dose is 10 mg/kg twice daily. Refer to Table 1.

Depending on the clinical response and tolerance, the daily dose can be increased up to 60 mg/kg daily (in two 30 mg/kg doses). Dose changes can be made in 10 mg/kg twice daily dose increments or decrements every two weeks. The lowest effective dose should be used.

The dosage in children 50 kg or greater is the same as in adults.

The physician should prescribe the most appropriate pharmaceutical form and strength according to weight and dose.

Table 1 Recommended dosing in children aged 4 years and older

Weight	Starting dose: 10 mg/kg twice daily	Maximum dose: 30 mg/kg twice daily
15 kg ⁽¹⁾	150 mg (1.5 mL) twice daily	450 mg (4.5 mL) twice daily
20 kg ⁽¹⁾	200 mg (2.0 mL) twice daily	600 mg (6.0 mL) twice daily
25 kg	250 mg (2.5 mL) twice daily	750 mg (7.5 mL) twice daily
From 50 kg ⁽²⁾	500 mg (5.0 mL) twice daily	1500 mg (15 mL) twice daily

⁽¹⁾ Children 20 kg or less should preferably start the treatment with levetiracetam 100 mg/mL oral solution.

⁽²⁾ Dosage in children and adolescents 50 kg or more is the same as in adults.

Infants and children less than 4 years of age

There are insufficient data to recommend the use of levetiracetam in children under 4 years of age.

Patients with renal impairment

The levetiracetam daily dose must be individualised according to renal function. For adult patients, refer to the following table and adjust the dose as indicated.

To use this dosing table, an estimate of the patient's creatinine clearance (CL_{cr}) in mL/min is needed. The CL_{cr} in mL/min may be estimated from serum creatinine (µmol/L) determination using the following formula:

$$\text{CL}_{\text{cr}} = \frac{[140 - \text{age}(\text{years})] \times \text{weight}(\text{kg})}{0.8136 \times \text{serum creatinine}(\mu\text{mol/L})} \quad (\times 0.85 \text{ for women})$$

Then CL_{cr} is adjusted for body surface area (BSA) as follows:

$$\text{CL}_{\text{cr}}(\text{mL}/\text{min}/1.73\text{m}^2) = \frac{\text{CL}_{\text{cr}}(\text{mL}/\text{min}) \times 1.73}{\text{BSA Subject}(\text{m}^2)}$$

Table 2 Adult dosage schedule based on renal function

Group	Creatinine clearance (mL/min/1.73m ²)	Dosage (mg)	Frequency (daily)
Normal	≥80	500 to 1500	Twice
Mild	50-79	500 to 1000	Twice
Moderate	30-49	250 to 750	Twice
Severe	<30	250 to 500	Twice
End-stage renal disease patients undergoing dialysis ⁽¹⁾	-	500 to 1000	Once ⁽²⁾

⁽¹⁾ A 750 mg loading dose is recommended on the first day of treatment with levetiracetam.

⁽²⁾ Following dialysis, a 250 to 500 mg supplemental dose is recommended.

For children with renal impairment, levetiracetam dose needs to be adjusted based on the renal function as levetiracetam clearance is related to renal function. This recommendation is based on a study in adult renally impaired patients.

Patients with hepatic impairment

No dose adjustment is needed in patients with mild and moderate hepatic impairment.

In patients with severe hepatic impairment, the creatinine clearance may underestimate the renal insufficiency. Therefore a 50% reduction of the daily maintenance dose is recommended when the creatinine clearance is $<60 \text{ mL/min/1.73m}^2$.

Method of administration

Incompatibilities

The formation of precipitate has been observed when mixing the infusion with phenytoin sodium in a PVC bag.

Hospira Levetiracetam concentrate for IV infusion must not be mixed with other medicinal products except those mentioned below.

Instructions for use and handling

Table 3 provides a summary for the recommended preparation and administration of Hospira Levetiracetam concentrate solution for IV infusion to achieve a total daily dose of 500 mg, 1000 mg, 2000 mg or 3000 mg in two divided doses:

Table 3 Preparation and administration of Hospira Levetiracetam concentrate for IV infusion

Dose	Withdrawal volume	Volume of diluent	Infusion time	Frequency of administration	Total daily dose
250 mg	2.5 mL (half 5 mL vial)	100 mL	15 minutes	Twice daily	500 mg/day
500 mg	5 mL (one 5 mL vial)	100 mL	15 minutes	Twice daily	1000 mg/day
1000 mg	10 mL (two 5 mL vials)	100 mL	15 minutes	Twice daily	2000 mg/day
1500 mg	15 mL (three 5 mL vials)	100 mL	15 minutes	Twice daily	3000 mg/day

Levetiracetam concentrate solution for IV infusion is for single use in one patient only.

Hospira Levetiracetam concentrate for IV infusion was found to be physically compatible and chemically stable when mixed with the following diluents and antiepileptic drugs for at least 24 hours and stored in PVC bags at controlled room temperature 15-30°C.

Hospira Levetiracetam concentrate for IV infusion is for single use in one patient only. Discard any residue. To reduce microbiological hazard, the product should be used immediately. If not used immediately, in-use storage times and conditions prior to use are the responsibility of the user and would be not longer than 24 hours at 2 to 8°C.

Diluents:

- Sodium chloride (0.9%) injection
- Lactated Ringer's injection
- Dextrose 5% injection

Other antiepileptic medicinal products:

- Lorazepam
- Diazepam
- Sodium valproate

4.3 Contraindications

Hypersensitivity to levetiracetam or other pyrrolidone derivatives or any of the excipients (see section 6.1 List of excipients).

4.4 Special warnings and precautions for use

In accordance with current clinical practice, if levetiracetam has to be discontinued it is recommended to withdraw it gradually.

Hospira Levetiracetam concentrate for IV infusion should not be administered by rapid infusion or direct IV injection.

To date, there is no data to support the use of levetiracetam concentrate for IV infusion for status epilepticus.

Due to its complete and linear absorption, plasma levels can be predicted from the oral dose of levetiracetam expressed as mg/kg bodyweight. There is no need therefore for plasma level monitoring of levetiracetam.

No data on the interaction of levetiracetam with alcohol are available.

Suicidal behaviour and ideation

Suicide, suicide attempt, suicidal ideation and behaviour have been reported in patients treated with antiepileptic agents (including levetiracetam). Antiepileptic drugs (AEDs), including levetiracetam, increase the risk of suicidal thoughts or behaviour in patients taking these drugs for any indication. The mechanism of this risk is not known. Patients treated with any AED for any indication should be monitored for the emergence or worsening of depression, suicidal thoughts or behaviour, and/or any unusual changes in mood or behaviour, and appropriate treatment should be considered.

Pooled analyses of 199 placebo-controlled clinical trials (mono- and adjunctive therapy) of 11 different AEDs showed that patients randomised to one of the AEDs had approximately twice the risk (adjusted Relative Risk 1.8, 95% CI:1.2, 2.7) of suicidal thinking or behaviour compared to patients randomised to placebo. In these trials, which had a median treatment duration of 12 weeks, the estimated incidence rate of suicidal behaviour or ideation among 27,863 AED-treated patients was 0.43%, compared to 0.24% among 16,029 placebo-treated patients, representing an increase of approximately one case of suicidal thinking or behaviour for every 530 patients treated. There were four suicides in drug-treated patients in the trials and none in placebo-treated patients, but the number is too small to allow any conclusion about drug effect on suicide.

The increased risk of suicidal thoughts or behaviour with AEDs was observed as early as one week after starting drug treatment with AEDs and persisted for the duration of treatment assessed. Because most trials included in the analysis did not extend beyond 24 weeks, the risk of suicidal thoughts or behaviour beyond 24 weeks could not be assessed.

The risk of suicidal thoughts or behaviour was generally consistent among drugs in the data analysed. The finding of increased risk with AEDs of varying mechanisms of action and across a range of indications suggests that the risk applies to all AEDs used for any indication. The

risk did not vary substantially by age (5 – 100 years) in the clinical trials analysed. Table 4 shows absolute and relative risk by indication for all evaluated AEDs.

Table 4 Risk by indication for antiepileptic drugs in the pooled analysis

Indication	Placebo patients with events/1000 patients	Drug patients with events/1000 patients	Relative Risk: Incidence of events in Drug patients/incidence in Placebo patients	Risk Difference: Additional Drug patients with events per 1000 patients
Epilepsy	1.0	3.4	3.5	2.4
Psychiatric	5.7	8.5	1.5	2.9
Other	1.0	1.8	1.9	0.9
Total	2.4	4.3	1.8	1.9

The relative risk for suicidal thoughts or behaviour was higher in clinical trials for epilepsy than in clinical trials for psychiatric or other conditions, but the absolute risk differences were similar for the epilepsy and psychiatric indications.

Anyone considering prescribing levetiracetam or any other AED must balance this risk with the risk of untreated illness. Epilepsy and many other illnesses for which AEDs are prescribed are themselves associated with morbidity and mortality and an increased risk of suicidal thoughts and behaviour. Should suicidal thoughts and behaviour emerge during treatment, the prescriber needs to consider whether the emergence of these symptoms in any given patient may be related to the illness being treated.

Patients, their caregivers, and families should be informed that AEDs increase the risk of suicidal thoughts and behaviour and should be advised of the need to be alert for the emergence of worsening of the signs and symptoms of depression, any unusual changes in mood or behaviour, or the emergence of suicidal thoughts, behaviour, or thoughts about self-harm. Behaviours of concern should be reported immediately to the treating doctor.

Psychiatric reactions and changes in behaviour

Levetiracetam may cause changes in behaviour (e.g. aggression, agitation, anger, anxiety, apathy, depression, hostility, and irritability) and psychotic symptoms. Patients treated with levetiracetam should be monitored for psychiatric signs and symptoms. If such behaviours are noticed, treatment adaptation or gradual discontinuation should be considered.

Seizure worsening

A paradoxical reaction of worsening of seizure may be observed especially when starting treatment or at increase in dose.

Lack of efficacy or seizure worsening has been reported in patients with epilepsy associated with SCN8A mutations.

Electrocardiogram QT interval prolongation

Rare cases of ECG QT interval prolongation have been observed during the post-marketing surveillance. Levetiracetam should be used with caution in patients with QTc-interval prolongation, in patients concomitantly treated with drugs affecting the QTc-interval, or in patients with relevant pre-existing cardiac disease or electrolyte disturbances.

Acute kidney injury

The use of levetiracetam has been very rarely associated with acute kidney injury with a time to onset ranging from a few days to several months.

Blood cell count

Cases of decreased blood cell counts (neutropenia, agranulocytosis, leucopenia, thrombocytopenia and pancytopenia) have been described in association with levetiracetam administration. Complete blood cell counts are advised in patients experiencing important weakness, pyrexia, recurrent infections or coagulation disorders (see section 4.8 Adverse effects (undesirable effects)).

Use in hepatic impairment

Monitoring of renal function in severe hepatic impaired patients is recommended before dose selection (see sections 4.2 Dose and method of administration and 5.2 Pharmacokinetic properties).

Use in renal impairment

The administration of levetiracetam to patients with renal impairment may require dose adaptation. Monitoring of renal function in severe hepatic impaired patients is recommended before dose selection (see section 4.2 Dose and method of administration).

Use in the elderly

See section 4.2 Dose and method of administration: Elderly (65 years and older).

Paediatric use

To date, there are no data to support the use of levetiracetam in patients less than 4 years of age.

Effects on laboratory tests

No data available.

4.5 Interactions with other medicines and other forms of interactions

In vitro, levetiracetam and its major metabolite (ucb L057) have been shown not to inhibit the major human liver cytochrome P450 isoforms, glucuronyl transferase, (valproic acid) and epoxide hydroxylase activities. In human hepatocytes in culture, levetiracetam did not cause enzyme induction.

Probenecid (500 mg four times daily) has been shown to inhibit the renal clearance of the major metabolite (ucb L057) but not levetiracetam. Nevertheless, the concentration of ucb L057 remains low. It is expected that other drugs excreted by active tubular secretion could also reduce the renal clearance of the metabolite. The effect of levetiracetam on probenecid was not studied and the effect of levetiracetam on other actively secreted drugs, e.g. non-steroidal anti-inflammatory drugs, and sulphonamides is unknown.

Concomitant administration of levetiracetam and methotrexate has been reported to decrease methotrexate clearance, resulting in increased/prolonged blood methotrexate concentration to potentially toxic levels. Blood methotrexate and levetiracetam levels should be carefully monitored in patients treated concomitantly with the two drugs.

Pre-marketing data from clinical studies conducted in adults indicate that levetiracetam did not influence the serum concentrations of existing AEDs (phenytoin, carbamazepine, valproic acid, phenobarbital, lamotrigine, gabapentin and primidone) and that these antiepileptic medicinal products did not influence the pharmacokinetics of levetiracetam.

Consistent with formal pharmacokinetic studies in adults, there has been no clear evidence of clinically significant drug interactions in paediatric patients receiving up to 60 mg/kg/day.

A retrospective assessment of pharmacokinetic interactions in children and adolescents with epilepsy (4 to 17 years) confirmed that adjunctive therapy with levetiracetam did not influence the steady-state serum concentrations of concomitantly administered carbamazepine, valproate, topiramate and lamotrigine. However, data suggested that enzyme-inducing antiepileptic medicinal products increase levetiracetam clearance by 22%. Dosage adjustment is not required.

Pharmacokinetic studies demonstrated a lack of interaction with digoxin, oral contraceptives (ethinylestradiol and levonorgestrel) and warfarin. Endocrine parameters (LH and progesterone) and prothrombin times were not modified.

No data on the influence of antacids on the absorption of levetiracetam are available.

4.6 Fertility, pregnancy and lactation

Effects on fertility

There are no human data on the effects of levetiracetam on male or female fertility. No adverse effects on male or female fertility or reproductive performance were observed in rats at oral doses of levetiracetam up to 1800 mg/kg/day (corresponding to approximately 6 times the maximal recommended clinical dose on a mg/m² basis) administered for at least two weeks prior to, and throughout, mating.

Use in pregnancy – Pregnancy Category B3

Category B3: Drugs which have been taken by only a limited number of pregnant women and women of childbearing age, without an increase in the frequency of malformation or other direct or indirect harmful effects on the human fetus having been observed. Studies in animals have shown evidence of an increased occurrence of fetal damage, the significance of which is considered uncertain in humans.

In rats and rabbits, levetiracetam and/or its metabolites cross the placenta and the fetal levels approximate maternal plasma levels. In these species, levetiracetam produced evidence of developmental toxicity at doses similar to or greater than human therapeutic doses.

Oral administration to female rats from two weeks prior to mating and throughout pregnancy and lactation was associated with increased incidences of minor fetal skeletal abnormalities and retarded offspring growth pre- and/or post-natally at doses ≥ 350 mg/kg/day (approximately equivalent to the maximal recommended clinical dose of 3000 mg/day on a mg/m² basis) and with increased pup mortality and offspring behavioural alterations at a dose of 1800 mg/kg/day (6 times the maximal human dose on a mg/m² basis). The developmental no-effect dose was 70 mg/kg/day (equivalent to 0.2 times the maximal human dose on a mg/m² basis). There was no overt maternal toxicity at the doses used in this study.

Oral administration to pregnant rabbits during the period of organogenesis resulted in increased embryofetal mortality and increased incidences of minor fetal skeletal abnormalities at doses ≥ 600 mg/kg/day (about 4 times the maximal human dose on a mg/m² basis) and in decreased fetal weights and increased incidences of minor fetal skeletal anomalies at a dose of 1800 mg/kg/day (12 times the maximal human dose on a mg/m² basis). The developmental no-effect dose was 200 mg/kg/day (1.3 times the maximal human dose on a mg/m² basis). Maternal toxicity was also observed at 1800 mg/kg/day.

Oral administration to pregnant rats during the period of organogenesis resulted in reduced fetal weight and increased incidence of embryofetal mortality and increased incidence of fetal skeletal variations at a dose of 3600 mg/kg/day (12 times the maximal human dose on a mg/m² basis). The developmental no-effect dose was 1200 mg/kg/day (4 times the maximal human dose on a mg/m² basis). There was no overt maternal toxicity.

Oral administration to rats during the late gestation and throughout lactation produced no adverse developmental or maternal effects at doses of up to 1800 mg/kg/day (6 times the maximal human dose on a mg/m² basis).

Neonatal and juvenile animal studies in rats and dogs demonstrated that there were no adverse effects seen in any of the standard developmental or maturation endpoints at doses of up to 1800 mg/kg/day corresponding to 30 times the maximum recommended human dose.

The risk of having an abnormal child as a result of antiepileptic medication is far outweighed by the dangers to the mother and fetus of uncontrolled epilepsy.

It is recommended that:

- women on AEDs receive pre-pregnancy counselling with regard to the risk of fetal abnormalities;
- AEDs should be continued during pregnancy and monotherapy should be used if possible at the lowest effective dose as risk of abnormality is greater in women taking combined medication;
- folic acid supplementation (5 mg) should be commenced four weeks prior to and continue for twelve weeks after conception;
- specialist prenatal diagnosis including detailed mid-trimester ultrasound should be offered.
- As with all antiepileptic medicines, sudden discontinuation of levetiracetam should be avoided as this may lead to breakthrough seizures that could have serious consequences for the woman and the unborn child.

A large amount of post-marketing data on pregnant women exposed to levetiracetam monotherapy (more than 1800, among which in more than 1500 exposure occurred during the 1st trimester) do not suggest an increase in the risk of major congenital malformations.

Limited evidence is available on the neurodevelopment of children exposed to levetiracetam monotherapy *in utero*. Information available from published epidemiological studies does not suggest an increased risk of neurodevelopmental disorders or delays.

Generally, therapy with multiple antiepileptic drugs (including polytherapy containing levetiracetam) is associated with a higher risk of major malformations than monotherapy.

Levetiracetam should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus. As with other antiepileptic drugs, physiological changes during pregnancy may affect Levetiracetam concentration. There have been reports of decreased levetiracetam concentrations during pregnancy. This decrease is more pronounced during the third trimester (up to 60% of baseline concentration before pregnancy). Appropriate clinical management of pregnant women treated with levetiracetam should be ensured. To monitor the outcome of pregnancy in women exposed to levetiracetam, doctors are encouraged to register pregnant patients taking levetiracetam on the Australian Pregnancy Register for Women on Antiepileptic Medication with Epilepsy and Allied Conditions by calling 1800 069 722.

Use in lactation

Levetiracetam and/or its metabolites are excreted in milk in lactating rats; peak milk concentrations occurred 3 hours after oral administration (milk:plasma ratio 0.9). Levetiracetam is excreted in human breast milk. Because of the potential for serious adverse reactions in breastfeeding infants from levetiracetam, breastfeeding is not recommended. If levetiracetam treatment is needed during breastfeeding, a decision should be made whether to discontinue breastfeeding or discontinue the drug, and the benefit/risk of the treatment should be weighed taking into account the importance of breastfeeding.

4.7 Effects on ability to drive and use machines

Levetiracetam has minor or moderate influence on the ability to drive and use machines. Due to possible different individual sensitivity, some patients might experience, at the beginning of treatment or following a dosage increase, somnolence or other central nervous system (CNS) related symptoms. Therefore, caution is recommended in those patients when performing skilled tasks, e.g. driving vehicles, or operating machinery. Patients are advised not to drive or use machines until it is established that their ability to perform such activities is not affected.

4.8 Adverse effects (undesirable effects)

The prescriber should be aware that following data were obtained from studies where levetiracetam was added to concomitant AED therapy. Therefore it was not possible in all cases to determine which agent(s), if any, was associated with adverse events. It is also difficult to predict the frequency of adverse events in the course of usual medical practice where patient characteristics and other factors may differ from those prevailing during clinical studies.

Adult patients

Levetiracetam has been administered to more than 3000 subjects and patients. Of these, 780 patients were treated for more than 6 months, 592 for more than 1 year, 366 for more than 2 years and 185 for more than 3 years.

1023 adult patients with epilepsy participated in controlled clinical trials (672 patients were treated with levetiracetam and 351 patients with placebo).

From placebo-controlled studies conducted in adults, 46.4% and 42.2% of patients experienced drug-related treatment-emergent adverse events in the levetiracetam group and placebo group, respectively. 2.4% and 2.0% of patients experienced serious drug-related treatment-emergent adverse events in the levetiracetam group and placebo group, respectively.

During monotherapy treatment with levetiracetam, 79.6% of subjects experienced at least one adverse event and 49.8% experienced at least one drug related undesirable effect. The most frequently reported adverse effects were fatigue and somnolence.

Very common adverse events ($\geq 10\%$)

The very common adverse events ($\geq 10\%$) were somnolence, asthenia, infection, headache and accidental injury. Of these, somnolence, asthenia and infection appeared to occur more frequently in levetiracetam-treated patients than in placebo-treated patients, whereas accidental injury was more common in the placebo group and headache was similarly reported in the two groups.

Table 5 Incidence (%) of very common treatment-emergent adverse events in adult placebo-controlled studies, by body system

Body System / Adverse Event	Levetiracetam group (N=672) %	Placebo group (N=351) %
Body as a Whole		
Accidental Injury	10.3	16.5
Asthenia	14.1	9.7
Headache	13.1	13.7
Infection	13.2	7.4
Nervous System		
Somnolence	14.9	9.7

In the pooled safety analysis, there was no clear dose-response relationship but incidence and severity of CNS related undesirable effects decreased over time.

More than 93% of events categorised under the COSTART preferred term “Infection” are symptoms of community acquired infections (common cold and upper respiratory tract infections).

There was no increase in incidence of other infections (lower respiratory tract infections, urinary tract infections, etc.). Minor, but statistically significant, decreases compared to placebo in total mean RBC count ($0.03 \times 10^6/\text{mm}^2$), mean haemoglobin (0.9 g/L), and mean haematocrit (0.38%) were seen in levetiracetam-treated patients in controlled trials. A total of 3.2% of treated and 1.8% of placebo patients had at least one possibly significant ($\leq 2.8 \times 10^9/\text{L}$) decreased white blood cells, and 2.4% for treated and 1.4% of placebo patients had at least one possible significant ($\leq 1.0 \times 10^9/\text{L}$) decreased neutrophil count. Of the treated patients with a low neutrophil count, all but one rose towards or to baseline with continued treatment. No patient was discontinued secondary to low neutrophil counts.

Common adverse events ($\geq 1\%$, $< 10\%$)

Table 6 Incidence (%) of common treatment-emergent adverse events in adult placebo-controlled studies, by body system

Body System / Adverse Event	Levetiracetam group (N=672) %	Placebo group (N=351) %
BODY AS A WHOLE		
Abdominal Pain	3.7	5.1
Back Pain	4.0	4.6
Chest Pain	1.3	1.1

Body System / Adverse Event	Levetiracetam group (N=672) %	Placebo group (N=351) %
Drug Level Increased	1.3	0.9
Fever	1.3	1.7
Flu Syndrome	4.2	6.0
Hostility	2.1	0.6
Pain	6.5	6.6
DIGESTIVE SYSTEM		
Anorexia	2.4	2.0
Diarrhoea	4.2	5.1
Dyspepsia	2.8	3.4
Gastroenteritis	1.2	0.9
Gingivitis	1.2	0.6
Nausea	4.2	4.6
Tooth Disorder	1.5	0.6
Vomiting	2.2	2.0
HAEMIC AND LYMPH SYSTEM		
Ecchymosis	1.5	1.1
METABOLIC / NUTR DIS		
Weight gain	1.2	1.1
NERVOUS SYSTEM		
Amnesia	1.6	0.3
Anxiety	1.6	1.1
Ataxia	2.5	1.4
Convulsion	6.0	6.8
Depression	4.0	2.3
Dizziness	9.2	4.3
Emotional Lability	1.6	0.3
Insomnia	3.0	2.8
Nervousness	3.9	1.7
Paraesthesia	1.9	1.7
Thinking abnormal	1.5	1.4
Tremor	1.5	1.7
Vertigo	2.5	1.4
RESPIRATORY SYSTEM		
Bronchitis	1.3	1.4
Cough Increased	2.1	1.7
Pharyngitis	5.7	3.7
Rhinitis	4.3	2.6
Sinusitis	2.1	0.9
SKIN AND APPENDAGES		
Rash	2.8	4.0
SPECIAL SENSES		
Amblyopia	1.2	1.4
Diplopia	2.4	1.7
Otitis media	1.2	0.9
UROGENITAL SYSTEM		
Urinary Tract Infection	1.9	3.4

The incidence of serious adverse events in placebo-controlled studies was 9.9% in the levetiracetam group versus 8.9% in the placebo group. Many of the serious adverse events are typical for a population of patients with epilepsy.

The serious adverse events which occurred in more than 1% of patients were convulsion (1.8% in levetiracetam group versus 1.4% in placebo group) and accidental injury (1.6% in both levetiracetam and placebo group).

Paediatric patients

A study conducted in paediatric patients (4 to 16 years of age) showed that 55.4% and 40.2% of the paediatric patients experienced undesirable effects in the levetiracetam and placebo groups, respectively. About 0.0% and 1.0% of the paediatric patients experienced serious undesirable effects in the levetiracetam and placebo groups, respectively. In the paediatric clinical study, 16.8% of patients receiving levetiracetam and 20.6% receiving placebo either discontinued or had a dose reduction as a result of an adverse event. The most commonly reported undesirable effects in the paediatric population were somnolence, hostility, nervousness, emotional lability, agitation, anorexia, asthenia and headache. Safety results in paediatric patients were consistent with the safety profile of levetiracetam in adults, except for behavioural and psychiatric undesirable effects which were more common in children than in adults (38.6% *versus* 18.6%). However, the relative risk was similar in children as compared to adults as there was also a higher incidence of behavioural psychiatric adverse events in the placebo group in children as compared to adults (27.8% *versus* 10.5%) (see Table 7).

Table 7 Incidence (%) of treatment-emergent adverse events in a placebo-controlled, add-on study in paediatric patients aged 4-16 years, by body system (adverse events occurred in at least 2% of levetiracetam-treated patients and occurred more frequently than placebo-treated patients)

Body System / Adverse Event	Levetiracetam group (N=101) %	Placebo group (N=97) %
BODY AS A WHOLE		
Accidental Injury	17	10
Asthenia	9	3
Pain	6	3
Flu Syndrome	3	2
Face Oedema	2	1
Neck Pain	2	1
Viral Infection	2	1
DIGESTIVE SYSTEM		
Vomiting	15	13
Anorexia	13	8
Diarrhoea	8	7
Gastroenteritis	4	2
Constipation	3	1
HAEMIC AND LYMPH SYSTEM		
Ecchymosis	4	1
METABOLIC / NUTR DIS		
Dehydration	2	1

Body System / Adverse Event	Levetiracetam group (N=101) %	Placebo group (N=97) %
NERVOUS SYSTEM		
Somnolence	23	11
Hostility	12	6
Nervousness	10	2
Personality Disorder	8	7
Dizziness	7	2
Emotional Lability	6	4
Agitation	6	1
Depression	3	1
Vertigo	3	1
Reflexes Increased	2	1
Confusion	2	0
RESPIRATORY SYSTEM		
Rhinitis	13	8
Cough Increased	11	7
Pharyngitis	10	8
Asthma	2	1
SKIN AND APPENDAGES		
Pruritis	2	0
Skin Discolouration	2	0
Vesiculobullous Rash	2	0
SPECIAL SENSES		
Conjunctivitis	3	2
Amblyopia	2	0
Ear Pain	2	0
UROGENITAL SYSTEM		
Albuminuria	4	0
Urine Abnormality	2	1

Other events occurring in 2% or more of paediatric patients treated with levetiracetam but as or more frequent in the placebo group were the following: abdominal pain, allergic reaction, ataxia, convulsion, epistaxis, fever, headache, hyperkinesia, infection, insomnia, nausea, otitis media, rash, sinusitis, status epilepticus (not otherwise specified), thinking abnormal, tremor, and urinary incontinence.

Other controlled clinical trials

The following adverse effects, listed by body system, have been observed in additional controlled clinical trials.

General disorders:

Very common: fatigue.

Respiratory system:

Very common: nasopharyngitis.

Nervous system:

Common: balance disorder, disturbance in attention, memory impairment.

Skin and subcutaneous tissue disorders:

Common: eczema, pruritus.

Eye disorders:

Common: vision blurred.

Blood and lymphatic system disorders:

Common: thrombocytopenia.

Musculoskeletal and connective tissue disorders:

Common: myalgia.

Psychiatric disorders:

Common: irritability, mood swings, personality disorder.

Post-marketing experience

In post-marketing experience, nervous system and psychiatric disorders have been most frequently reported.

In addition to the adverse reactions reported during clinical studies and listed above, the following adverse reactions have been reported in post-marketing experience. Data are insufficient to support an estimate of their incidence in the population to be treated.

- *Blood and lymphatic system disorders*: pancytopenia with bone marrow suppression identified in some of these cases, agranulocytosis, leucopenia and neutropenia.
- *Cardiac disorders*: electrocardiogram QT prolonged.
- *Immune system disorders*: drug reaction with eosinophilia and systemic symptoms (DRESS), hypersensitivity (including angioedema and anaphylaxis).
- *Psychiatric disorders*: abnormal behaviour, aggression, anger, panic attack, confusion, hallucination, psychotic disorder, suicide (including completed suicide), suicide attempt, suicidal ideation and delirium.
- *Nervous system disorders*: choreoathetosis, dyskinesia, lethargy, gait disturbance, encephalopathy, seizures aggravated, neuroleptic malignant syndrome.
- *Skin and subcutaneous tissue disorders*: toxic epidermal necrolysis, Stevens-Johnson syndrome, erythema multiforme and alopecia, in several alopecia cases, recovery was observed when levetiracetam was discontinued.
- *Musculoskeletal and connective tissue disorders*: muscular weakness, rhabdomyolysis and blood creatine phosphokinase increased.
- *Liver and biliary system disorders*: hepatitis, hepatic failure and abnormal liver function test.
- *Renal and urinary disorders*: acute kidney injury.
- *Metabolic and nutritional disorders*: weight loss, pancreatitis, hyponatraemia.

Description of selected adverse reactions

The prevalence of neuroleptic malignant syndrome, rhabdomyolysis and blood creatine phosphokinase increase is significantly higher in Japanese patients when compared to non-Japanese patients.

Rare cases of QT prolongation have been seen in post-marketing surveillance.

Rare cases of development of obsessive-compulsive disorders (OCD) in patients with underlying history of OCD or psychiatric disorders have been observed in post-marketing surveillance.

The risk of anorexia is higher when levetiracetam is co-administered with topiramate.

Cases of encephalopathy generally occurred at the beginning of the treatment (few days to a few months) and were reversible after treatment discontinuation.

Reporting suspected adverse effects

Reporting suspected adverse reactions after registration of the medicinal product is important. It allows continued monitoring of the benefit-risk balance of the medicinal product. Healthcare professionals are asked to report any suspected adverse reactions at www.tga.gov.au/reporting-problems.

4.9 Overdose

Symptoms

The highest known dose of levetiracetam received in the clinical development program was 6000 mg/day. Other than drowsiness, there were no adverse events in the few known cases of overdose in clinical trials. Cases of somnolence, agitation, aggression, depressed level of consciousness, respiratory depression and coma were observed with levetiracetam overdoses in post-marketing use.

Management of overdose

There is no specific antidote for levetiracetam. Treatment for an overdose will be symptomatic and may include haemodialysis. The dialyser extraction efficiency is 60% for levetiracetam and 74% for the major metabolite (ucb L057).

For information on the management of overdose, contact the Poisons Information Centre on 13 11 26 (Australia).

5. PHARMACOLOGICAL PROPERTIES

5.1 Pharmacodynamic properties

Mechanism of action

The precise mechanism of action by which levetiracetam induces seizure protection still remains to be fully elucidated, but appears to be unrelated to the mechanisms of current antiepileptic drugs. *In vitro* and *in vivo* experiments suggest that levetiracetam does not alter basic cell characteristics and normal neurotransmission.

In vitro studies show that levetiracetam affects intraneuronal Ca²⁺ levels by partial inhibition of N-type Ca²⁺ currents and by reducing the release of Ca²⁺ from intraneuronal stores. In addition, it partially reverses the reductions in GABA- and glycine-gated currents induced by zinc and β -carbolines. Furthermore, levetiracetam has been shown in *in vitro* studies to bind to a specific site in rodent brain tissue. This binding site is the synaptic vesicle protein 2A,

believed to be involved in vesicle fusion and neurotransmitter exocytosis. Levetiracetam and related analogues show a rank order of affinity for binding to the synaptic vesicle protein 2A which correlates with the potency of their anti-seizure protection in the mouse audiogenic model of epilepsy. This finding suggests that the interaction between levetiracetam and the synaptic vesicle protein 2A seems to contribute to the antiepileptic mechanism of action of the drug.

Pharmacodynamics

In animals

Levetiracetam is not active in the classical screening models for anticonvulsants however induces potent protection in a broad range of animal models of partial and primary generalised seizures, with an unusually high safety margin between therapeutic doses and doses inducing adverse effects.

Levetiracetam also displays potential antiepileptogenic properties by dose-dependently inhibiting the development of kindling, even after discontinuation of the active substance.

Withdrawal from chronic treatment did not decrease the seizure threshold. Anxiolytic action and an absence of undesirable effects on cognitive function have also been observed.

The major metabolite, ucb L057, is inactive in seizure models.

In man

Both partial and generalised epilepsy models (epileptiform discharge/photoparoxysmal response) confirmed the broad spectrum preclinical pharmacological profile.

Clinical trials

Effectiveness in Partial Onset Seizures in Adults and Adolescents

Monotherapy

The monotherapy study was designed as a double-blind, parallel group, non-inferiority comparison of levetiracetam and controlled-released (CR) formulation of carbamazepine in patients 16 years of age or older with newly diagnosed epilepsy. The seizures were to be either unprovoked partial seizures (type IA (simple partial seizures with unimpaired consciousness), IB (complex partial seizures with impaired consciousness), or IC (partial seizures secondarily generalised (with clear focal origin)) or IIE (generalised tonic-clonic seizure (without clear focal origin)). These different types of seizures were classified according to the International Classification of Epileptic Seizures. The study was performed in 85 centres in 13 countries (Europe and South Africa).

At the end of the 1-week screening period, eligible subjects were stratified by seizure type (IA/IB/IC or IC/IIE without clear focal origin) and randomly assigned to receive carbamazepine CR (N=291) or levetiracetam (N=285), for up to 121 weeks depending on response. Conservatively, carbamazepine CR was used to minimise adverse effects. The maximal duration for an individual subject was 121 weeks.

After a 1-week screening period (no study drug intake), the subject was randomised and entered a 2-week up-titration period to the first target daily dose (levetiracetam 1000 mg / carbamazepine CR 400 mg), followed by a one-week stabilisation period and an evaluation period of 26 weeks in order to achieve a 6-month seizure freedom (primary efficacy

endpoint), and followed by a maintenance period of 26 additional weeks in order to assess safety and maintenance of efficacy.

If a seizure occurred during the evaluation period, dose escalation (made over a 2-week period) to the second target daily dose (levetiracetam 2000 mg / carbamazepine 800 mg) was foreseen. This was followed by a 1-week stabilisation period, a new evaluation period of 26 weeks and a maintenance period of 26 additional weeks. The same strategy was applied if a seizure occurred during the evaluation period at the second dose level: dose escalation (made over a 2-week period) to the third target daily dose (levetiracetam 3000 mg / carbamazepine 1200 mg), followed by a one-week stabilisation period, a new evaluation period of 26 weeks and a maintenance period of 26 additional weeks. Fall-back option: in case a subject did not tolerate the second or third study drug target dose, he/she had the opportunity, during the evaluation or the maintenance period, to have one fallback to an intermediate dose (decrease by 200 mg/day for carbamazepine CR or by 500 mg/day for levetiracetam) and to continue in the trial on that basis. The subject could not resume the previous dose and could not have further up-titration in case a new seizure occurred.

Five hundred and seventy-six (576) subjects were randomised. Approximately one half of the patients in each treatment group completed the study (53.6% of the patients randomised to carbamazepine CR and 54.0% of the patients randomised to levetiracetam), similar between the two treatment groups. The distribution by seizure type categories was similar in both treatment groups, with around 86.7% of subjects lastly classified as experiencing partial seizures with clear focus origin. The majority of subjects remained at dose level 1 (81.7% of subjects randomised to carbamazepine CR and 73.4% of subjects randomised to levetiracetam in the per-protocol (PP) population).

The prospectively defined primary endpoint was the proportion of subjects from the PP population with 6-month seizure freedom at the last evaluated dose.

One hundred seventy-three (73.0%) of the PP subjects in the levetiracetam arm were seizure-free for at least 6 months at the last evaluated dose, compared to 171 subjects (72.8%) in the carbamazepine CR arm. The adjusted absolute difference levetiracetam and carbamazepine CR (95% two-sided confidence interval CI) obtained from a logistic regression model including a factor for the seizure type category as last assessed (IA/IB/IC versus IC/IE) equalled 0.2% (-7.8%; 8.2%). The lower limit of the CI (-7.8%) was above the non-inferiority limit set by protocol (-15%) for this primary efficacy analysis, and therefore levetiracetam can be considered as non-inferior to carbamazepine CR on the proportion of subjects seizure-free at least 6 months at the first evaluated dose in the PP population. Considering the other clinically relevant end-point, 56.6% and 58.5% of subjects on levetiracetam and carbamazepine CR respectively were seizure free for 1 year.

Add-on Therapy

The effectiveness of levetiracetam tablets as adjunctive therapy (added to other antiepileptic drugs (AEDs) in adults was established in three multicentre, randomised, double-blind, placebo-controlled clinical studies in patients who had refractory partial onset seizures with or without secondary generalisation. In these studies, 904 patients were randomised to placebo, 1000 mg, 2000 mg or 3000 mg/day. Patients enrolled in Study 1 or Study 2 had refractory partial onset seizures for at least 2 years and had taken two or more classical AEDs. Patients enrolled in Study 3 had refractory partial onset seizures for at least 1 year and had taken one classical AED. At the time of the study, patients were taking a stable dose regimen of at least

one and could take a maximum of two AEDs. During the baseline period, patients had to have experienced at least two partial onset seizures during each 4-week period.

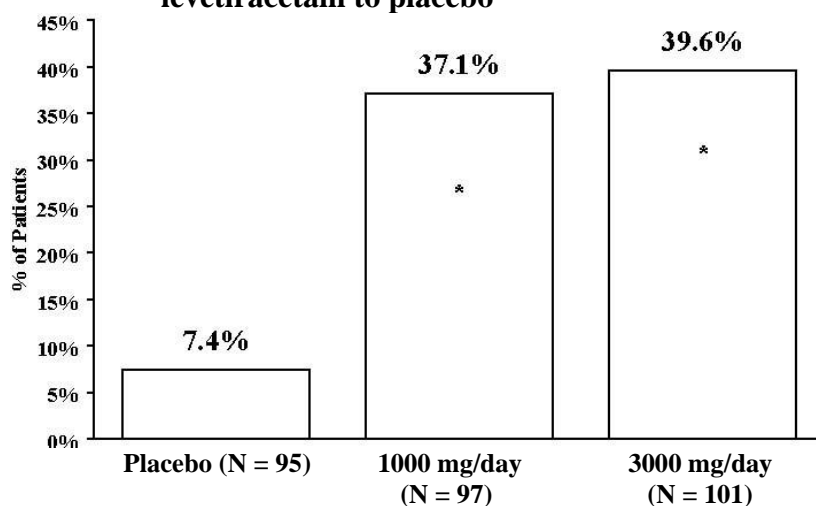
Study 1: Study 1 was a double-blind, placebo-controlled, parallel-group study conducted at 41 sites in the United States comparing levetiracetam 1000 mg/day (N=97), levetiracetam 3000 mg/day (N=101) and placebo (N=95) given in equally divided doses twice daily. After a prospective baseline period of 12 weeks, patients were randomised to one of the three treatment groups described above. The 18-week treatment period consisted of a 6-week titration period, followed by a 12-week fixed dose evaluation period, during which concomitant AED regimens were held constant. The primary measure of effectiveness was a between group comparison of the percent reduction in weekly partial seizure frequency relative to placebo over the entire randomised treatment period (titration + evaluation period). Secondary outcome variables included the responder rate (incidence of patients with $\geq 50\%$ reduction from baseline in partial onset seizure frequency). The results of the analysis of Study 1 are displayed in Table 8.

Table 8 Reduction in mean over placebo in weekly frequency of partial onset seizures in Study 1

	Placebo (N=95)	Levetiracetam 1000 mg/day (N=97)	Levetiracetam 3000 mg/day (N=101)
Percent reduction in partial seizure frequency over placebo	-	26.1% P<0.001	30.1% P<0.001

The percentage of patients (y-axis) who achieved $\geq 50\%$ reduction in weekly seizure rates from baseline in partial onset seizure frequency over the entire randomised treatment period (titration + evaluation period) within the three treatment groups (x-axis) is presented in Figure 1.

Figure 1. Responder rate ($\geq 50\%$ reduction from baseline) in Study 1 comparing levetiracetam to placebo



*P<0.001 versus placebo

Study 2: Study 2 was a double-blind, placebo-controlled, crossover study conducted at 62 centres in Europe comparing levetiracetam 1000 mg/day (N=106), levetiracetam 2000 mg/day (N=105) and placebo (N=111) given in equally divided doses twice daily.

The first period of the study (Period A) was designed to be analysed as a parallel-group study. After a prospective baseline period of up to 12 weeks, patients were randomised to one of the three treatment groups described above. The 16-week treatment period consisted of the 4-week titration period followed by a 12-week fixed dose evaluation period, during which concomitant

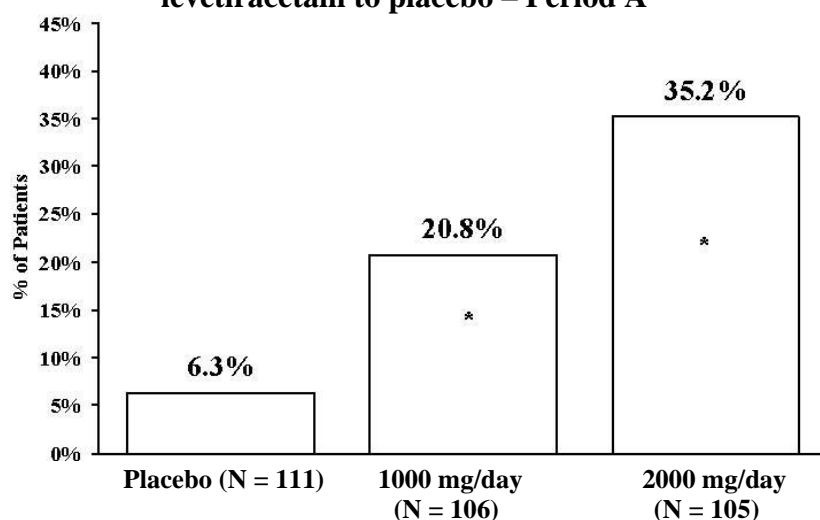
AED regimens were held constant. The primary measure of effectiveness was a between group comparison of the percent reduction in weekly partial seizure frequency relative to placebo over the entire randomised treatment period (titration + evaluation period). Secondary outcome variables included the responder rate (incidence of patients with $\geq 50\%$ reduction from baseline in partial onset seizure frequency). The results of the analysis of Period A are displayed in Table 9.

Table 9 Reduction in mean over placebo in weekly frequency of partial onset seizures in Study 2 – Period A

	Placebo (N=111)	Levetiracetam 1000 mg/day (N=106)	Levetiracetam 2000 mg/day (N=105)
Percent reduction in partial seizure frequency over placebo	-	17.1% P \leq 0.001	21.4% P \leq 0.001

The percentage of patients (y-axis) who achieved $\geq 50\%$ reduction in weekly seizure rates from baseline in partial onset seizure frequency over the entire randomised treatment period (titration + evaluation period) within the three treatment groups (x-axis) is presented in Figure 2.

Figure 2 Responder rate ($\geq 50\%$ reduction from baseline) in Study 2 comparing levetiracetam to placebo – Period A



*P $<$ 0.001 versus placebo

The comparison of levetiracetam 2000 mg/day to levetiracetam 1000 mg/day for responder rate was statistically significant (P=0.02). Analysis of the trial as a crossover yielded similar results.

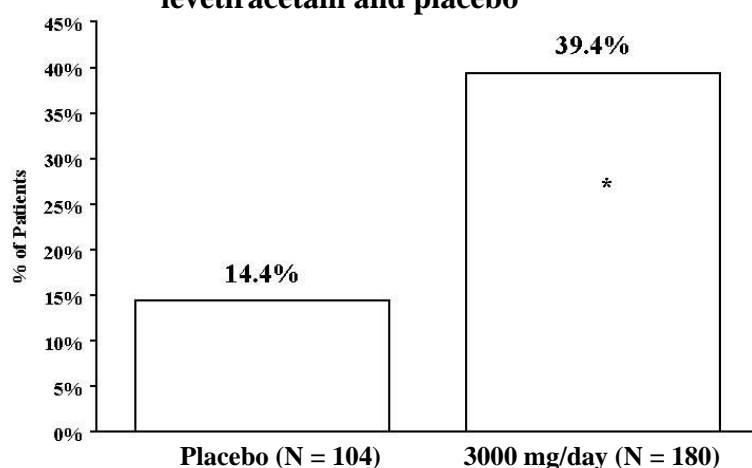
Study 3: Study 3 was a double-blind, placebo-controlled, parallel-group study conducted at 47 centres in Europe comparing levetiracetam 3000 mg/day (N=180) and placebo (N=104) in patients with refractory partial onset seizures, with or without secondary generalisation, receiving only one concomitant AED. Study drug was given in two divided doses. After a prospective baseline period of 12 weeks, patients were randomised to one of two treatment groups described above. The 16-week treatment period consisted of a 4-week titration period, followed by a 12-week fixed dose evaluation period, during which concomitant AED doses were held constant. The primary measure of effectiveness was a between group comparison of the percent reduction in weekly seizure frequency relative to placebo over the entire randomised treatment period (titration + evaluation period). Secondary outcome variables included the responder rate (incidence of patients with $\geq 50\%$ reduction from baseline in partial onset seizure frequency). Table 10 displays the results of the analysis of Study 3.

Table 10 Reduction in mean over placebo in weekly frequency of partial onset seizures in Study 3

	Placebo (N=104)	Levetiracetam 3000 mg/day (N=180)
Percent reduction in partial seizure frequency over placebo	-	23.0% P<0.001

The percentage of patients (y-axis) who achieved $\geq 50\%$ reduction in weekly seizure rates from baseline in partial onset seizure frequency over the entire randomised treatment period (titration + evaluation period) within the two treatment groups (x-axis) is presented in Figure 3.

Figure 3 Responder rate ($\geq 50\%$ reduction from baseline) in Study 3 comparing levetiracetam and placebo



*P<0.001 versus placebo

Effectiveness in Partial Onset Seizures in Paediatric Patients with Epilepsy

The effectiveness of levetiracetam as adjunctive therapy (added to other AEDs) in paediatric patients was established in a multicentre, randomised double-blind, placebo-controlled study, conducted at 60 sites in North America, in children and adolescents 4 to 16 years of age with partial seizures uncontrolled by standard AEDs. Eligible patients on a steady dose of 1-2 AEDs, who still experienced at least 4 partial onset seizures during the 4 weeks prior to screening, as well as at least 4 partial onset seizures in each of the two 4-week baseline periods, were randomised to receive either levetiracetam or placebo. The population included 198 patients (levetiracetam N=101, placebo N=97) with uncontrolled partial onset seizures, whether or not secondarily generalised. The study consisted of an 8-week baseline period and 4-week titration period followed by a 10-week evaluation period. Dosing was initiated at a target dose of 20 mg/kg/day in two divided doses. During the treatment period, levetiracetam doses were adjusted in 20 mg/kg/day increments, at 2-week intervals to the target dose of 60 mg/kg/day (or 40 mg/kg/day as a maximum tolerated dose).

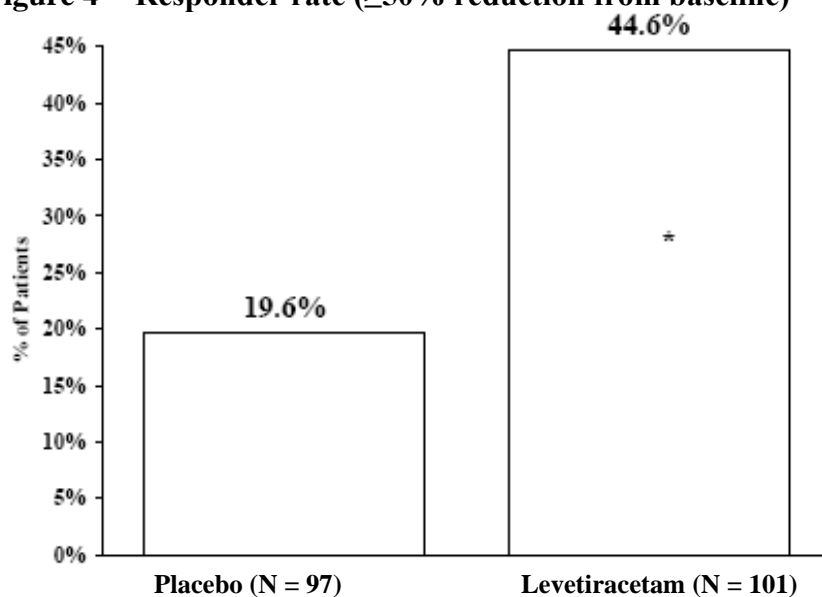
The primary measure of effectiveness was a between group comparison of the percent reduction in weekly partial seizure frequency relative to placebo over the entire randomised treatment period (titration + evaluation period). Secondary outcome variables included the responder rate (incidence of patients with $\geq 50\%$ reduction from baseline in partial onset seizure frequency per week). Table 11 displays the results of this study.

Table 11 Reduction in mean over placebo in weekly frequency of partial onset seizures

	Placebo (N=97)	Levetiracetam (N=101)
Percent reduction in partial seizure frequency over placebo	-	26.8%*

* P=0.0002

The percentage of patients (y-axis) who achieved $\geq 50\%$ reduction in weekly seizure rates from baseline in partial onset seizure frequency over the entire randomised treatment period (titration + evaluation period) within the two treatment groups (x-axis) is presented in Figure 4.

Figure 4 Responder rate ($\geq 50\%$ reduction from baseline)

*P = 0.0002 versus placebo

Effectiveness in Myoclonic Seizures in Patients ≥ 12 Years of Age with Juvenile Myoclonic Epilepsy (JME)

The effectiveness of levetiracetam as adjunctive therapy in patients 12 years of age and older with juvenile myoclonic epilepsy experiencing myoclonic seizures was established in one multicentre, randomised, double-blind, placebo-controlled study, conducted at 37 sites in 14 countries. Eligible patients on a stable dose of 1 antiepileptic drug (AED) experiencing one or more myoclonic seizures per day for at least 8 days during the prospective 8-week baseline period were randomised to either levetiracetam or placebo. The population included 120 patients (levetiracetam N=60, placebo N=60) with idiopathic generalised epilepsy which included juvenile myoclonic epilepsy, juvenile absence epilepsy, or epilepsy with generalised tonic-clonic seizures on awakening. The majority were patients with juvenile myoclonic epilepsy. Patients were titrated over 4 weeks to a target dose of 3000 mg/day and treated at a stable dose of 3000 mg/day over 12 weeks (evaluation period). Study drug was given in 2 divided doses.

The primary measure of effectiveness was the proportion of patients with at least 50% reduction in the number of days per week with one or more myoclonic seizures during the treatment period (titration + evaluation periods) as compared to baseline. Secondary outcome variables included seizure frequency per week over the treatment period. Table 12 displays the results of this study.

Table 12 Responder rate ($\geq 50\%$ reduction from baseline) in myoclonic seizure days per week for patients with juvenile myoclonic epilepsy

	Placebo (N=60)	Levetiracetam (N=60)
Percentage of responders	23.3%	58.3%*

* $P=0.0002$

Effectiveness in Primary Generalised Tonic-Clonic Seizures in Patients ≥ 4 Years of Age with Idiopathic Generalised Epilepsy

The effectiveness of levetiracetam as adjunctive therapy (added to other AEDs in patients 4 years of age and older with idiopathic generalised epilepsy experiencing primary generalised tonic-clonic (PGTC) seizures) was established in one multicentre, randomised, double-blind, placebo-controlled study, conducted at 50 sites in 8 countries. Eligible patients on a stable dose of 1 or 2 AEDs experiencing at least 3 PGTC seizures during the 8-week combined baseline period (at least one PGTC seizure during the 4 weeks prior to the prospective baseline period and at least one PGTC seizure during the 4-week prospective baseline period) were randomised to either levetiracetam or placebo. The 8-week combined baseline period is referred to as “baseline” in the remainder of this section. The population included 164 patients (levetiracetam N=80, placebo N=84) with idiopathic generalised epilepsy (predominately juvenile myoclonic epilepsy, juvenile absence epilepsy, childhood absence epilepsy, or epilepsy with Grand Mal seizures on awakening) experiencing PGTC seizures. Each of these syndromes of idiopathic generalised epilepsy was well represented in this patient population. Patients were titrated over 4 weeks to a target dose of 3000 mg/day for adults or a paediatric target dose of 60 mg/kg/day and treated at a stable dose of 3000 mg/day (or 60 mg/kg/day for children) over 20 weeks (evaluation period). Study drug was given in 2 equally divided doses per day.

The primary measure of effectiveness was the percent reduction from baseline in weekly PGTC seizure frequency for levetiracetam and placebo treatment groups over the treatment period (titration + evaluation periods). There was a statistically significant decrease from baseline in PGTC frequency in the levetiracetam-treated patients compared to the placebo-treated patients.

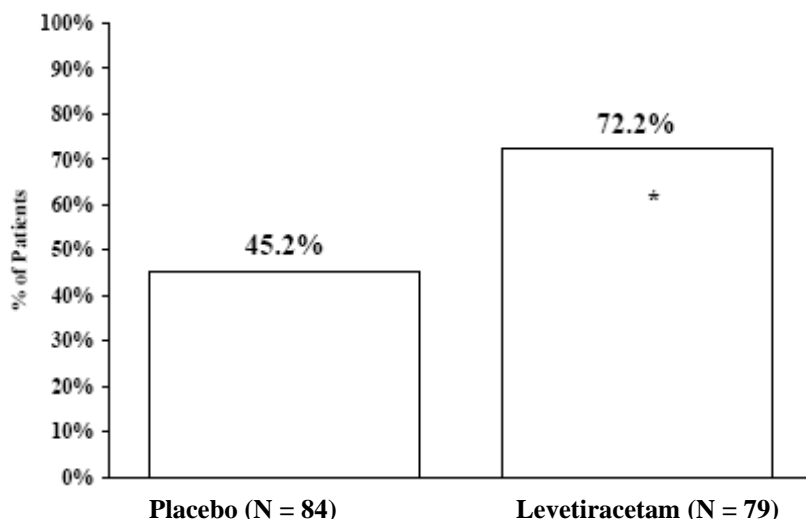
Table 13 Median percent reduction from baseline in PGTC seizure frequency per week

	Placebo (N=84)	Levetiracetam (N=78)
Percent reduction in PGTC seizure frequency	44.6%	77.6%*

*statistically significant versus placebo

The percentage of patients (y-axis) who achieved $\geq 50\%$ reduction in weekly seizure rates from baseline in PGTC seizure frequency over the entire randomised treatment period (titration + evaluation period) within the two treatment groups (x-axis) is presented in Figure 5.

Figure 5 Responder rate ($\geq 50\%$ reduction from baseline) in PGTC seizure frequency per week



*statistically significant versus placebo

When levetiracetam was used to treat PGTC seizures in adults and adolescents with idiopathic generalised epilepsy, there was no effect on the frequency of absences.

5.2 Pharmacokinetic properties

Levetiracetam is a highly soluble and permeable compound. The pharmacokinetic profile is linear and time-independent with low intra- and inter-subject variability. There is no modification of the clearance after repeated administration. There is no evidence for any relevant gender, race or circadian variability. The pharmacokinetic profile is comparable in healthy volunteers and in patients with epilepsy.

Due to its complete and linear absorption, plasma levels can be predicted from the oral dose of levetiracetam expressed as mg/kg bodyweight. Therefore there is no need for plasma level monitoring of levetiracetam.

A significant correlation between saliva and plasma concentrations has been shown in adults and children (ratio of saliva/plasma concentrations ranged from 1 to 1.7 for oral tablet formulation and after 4 hours post-dose for oral solution formulation).

A single dose of 1500 mg levetiracetam diluted in 100 mL of a compatible diluent and infused intravenously over 15 minutes is bioequivalent to 1500 mg levetiracetam oral intake, given as three 500 mg tablets.

The intravenous administration of doses up to 4000 mg diluted in 100 mL of 0.9% sodium chloride infused over 15 minutes and doses up to 2500 mg diluted in 100 mL of 0.9% sodium chloride infused over 5 minutes was evaluated. The pharmacokinetic and safety profiles did not identify any safety concerns.

Adults and Adolescents

Absorption

Levetiracetam is rapidly absorbed after oral administration. Oral absolute bioavailability is close to 100%. Peak plasma concentrations (C_{max}) are achieved at 1.3 hours after dosing. Steady state is achieved after two days of a twice daily administration schedule. Peak

concentrations (C_{max}) are typically 31 $\mu\text{g/mL}$ and 43 $\mu\text{g/mL}$ following a single 1000 mg dose and repeated 1000 mg b.i.d. dose respectively. The extent of absorption is dose-independent and is not altered by food, but the rate of absorption is slightly reduced.

Distribution

No tissue distribution data are available in humans. Neither levetiracetam nor its major metabolite (ucb L057) are significantly bound to plasma proteins (<10%). The volume of distribution of levetiracetam is approximately 0.5 to 0.7 L/kg, a value close to the volume of distribution of intracellular and extracellular water.

Metabolism

The major metabolic pathway (24% of the dose) is an enzymatic hydrolysis of the acetamide group. Production of this metabolite, ucb L057, is not supported by liver cytochrome P450 isoforms. Hydrolysis of the acetamide group was measurable in a large number of tissues including whole blood but not plasma. The metabolite ucb L057 is pharmacologically inactive.

Two minor metabolites were also identified. One was obtained by hydroxylation of the pyrrolidone ring (1.6% of the dose) and the other one by opening of the pyrrolidone ring (0.9% of the dose).

Other unidentified components accounted for only 0.6% of the dose.

No enantiomeric interconversion was evidenced *in vivo* for either levetiracetam or its major metabolite ucb L057.

In vitro, levetiracetam and its primary metabolite have been shown not to inhibit the major human liver cytochrome P450 isoforms (CYP3A4, 2A6, 2C9, 2C19, 2D6, 2E1 and 1A2), glucuronyl transferase (UGT1A1 and UGT1A6) and epoxide hydroxylase activities. In addition, levetiracetam does not affect the *in vitro* glucuronidation of valproic acid.

In human hepatocytes *in vitro*, levetiracetam had no effect on CYP1A1/2, or UGT isoform activities (including ethinyl-estradiol conjugation). Levetiracetam caused mild induction of CYP2B6 and CYP3A4, but only at high concentrations not considered to be clinically relevant. Therefore the interaction of levetiracetam with other substances, or *vice versa*, is unlikely.

Excretion

The plasma half-life in adults was 7 ± 1 hours and did not vary either with dose, route of administration or repeated administration. The mean total body clearance was 0.96 mL/min/kg.

The major route of excretion was via urine, accounting for a mean 95% of the dose, with approximately 93% of the dose excreted within 48 hours. Excretion via faeces accounted for only 0.3% of the dose. During the first 48 hours, the cumulative urinary excretion of levetiracetam and its major metabolite (ucb L057) accounted for 66% and 24% of the dose respectively.

The renal clearance of levetiracetam is 0.6 mL/min/kg, indicating that it is excreted by glomerular filtration with subsequent tubular reabsorption. The renal clearance of the major metabolite, ucb L057, is 4.2 mL/min/kg indicating active tubular secretion in addition to glomerular filtration.

Elderly

In elderly patients, the half-life is increased by about 40% (10 to 11 hours) and is attributed to the decrease in renal function in this population (refer to Section 4.2 Dose and method of administration).

Children (4 to 12 years of age)

Following single oral dose administration (20 mg/kg) to epileptic children (6 to 12 years of age), the half-life of levetiracetam was 6.0 ± 1.1 hours. The apparent body clearance was approximately 30% higher than in epileptic adults.

Following repeated oral dose administration (20 to 60 mg/kg/day) to epileptic children (4 to 12 years of age), levetiracetam was rapidly absorbed. Peak plasma concentration was observed 0.5 to 1.0 hour after dosing. Linear and dose proportional increases were observed for peak plasma concentrations and area under the curve. The elimination half-life was approximately 5 hours. The apparent body clearance was 1.1 mL/min/kg.

Infants and children (1 month to 4 years of age)

Following single dose administration (20 mg/kg) of a 10% oral solution to epileptic children (1 month to 4 years of age), levetiracetam was rapidly absorbed and peak plasma concentrations were observed approximately 1 hour after dosing. The pharmacokinetic results indicated that half-life was shorter (5.3 h) than for adults (7.2 h) and apparent clearance was faster (1.5 mL/min/kg) than for adults (0.96 mL/min/kg).

Renal impairment

The apparent body clearance of both levetiracetam and its major metabolite (ucb L057) is correlated to the creatinine clearance. It is therefore recommended to adjust the maintenance daily dose of levetiracetam, based on creatinine clearance in patients with moderate and severe renal impairment (refer to section 4.2 Dose and method of administration).

In anuric end-stage renal disease adult subjects the half-life was approximately 25 and 3.1 hours during inter- and intra-dialytic periods respectively. The fractional removal of levetiracetam was 51% during a typical 4-hour dialysis session.

Hepatic impairment

In subjects with mild and moderate hepatic impairment, there was no relevant modification of the clearance of levetiracetam. In most subjects with severe hepatic impairment, the clearance of levetiracetam was reduced by more than 50% due to concomitant renal impairment (refer to section 4.2 Dose and method of administration).

5.3 Preclinical safety data

Genotoxicity

Levetiracetam was negative in gene mutation assays (bacterial, Chinese hamster ovary/HGPRT locus) and in assays for chromosomal damage *in vitro* and *in vivo* (Chinese hamster ovary cells, mouse micronucleus assay). The hydrolysis product and major human metabolite ucb L057 were not mutagenic in bacterial reverse mutation assays or the *in vitro* mouse lymphoma assay.

Carcinogenicity

There was no evidence of carcinogenicity following administration of levetiracetam in the diet to rats or orally to mice for 104 weeks, associated with respective systemic exposures (plasma AUC) up to 4-fold and 8-fold that in humans at the maximal recommended clinical dose of 3000 mg/day.

6. PHARMACEUTICAL PARTICULARS

6.1 List of excipients

sodium acetate trihydrate
sodium chloride
glacial acetic acid
water for injections
nitrogen

6.2 Incompatibilities

See section 4.2 Dose and method of administration: Incompatibilities.

6.3 Shelf life

In Australia, information on the shelf life can be found on the public summary of the Australian Register of Therapeutic Goods (ARTG). The expiry date can be found on the packaging.

6.4 Special precautions for storage

Hospira Levetiracetam concentrate for IV infusion is stored below 25°C.

6.5 Nature and contents of container

Hospira Levetiracetam concentrate for IV infusion is a sterile, clear and colourless aqueous solution presented in clear glass vials. Each vial contains 500 mg of levetiracetam (500 mg/ 5 mL). The vial is closed with bromobutyl rubber stopper and aluminum seal with plastic flip-off top.

Hospira Levetiracetam concentrate for IV infusion is supplied in single-use 5 mL vials and available in cartons of 10 vials. Each vial contains a slight excess of approximately 0.4 mL of the labelled volume to permit withdrawal and administration of the labelled volume.

6.6 Special precautions for disposal

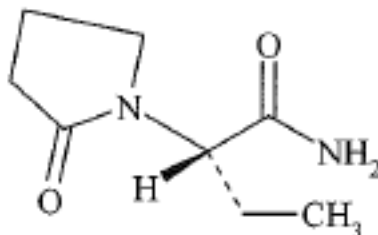
In Australia, any unused medicine or waste material should be disposed of in accordance with local requirements.

6.7 Physicochemical properties

Levetiracetam is a white to off-white powder with a faint odour and a bitter taste. It is very soluble in water (104 g/100 mL). It is freely soluble in chloroform (65.3 g/100 mL), soluble in methanol (53.6 g/100 mL), soluble in ethanol (16.5 g/100 mL), sparingly soluble in acetonitrile (5.7 g/100 mL) and practically insoluble in n-hexane.

Chemical name: (S)- α -ethyl-2-oxo-1-pyrrolidineacetamide

Chemical structure



Molecular formula: C₈H₁₄N₂O₂

Molecular weight: 170.2

CAS number

102767-28-2

7. MEDICINE SCHEDULE (POISONS STANDARD)

Schedule 4 (Prescription Only Medicine)

8. SPONSOR

Pfizer Australia Pty Ltd
Level 17, 151 Clarence Street
Sydney NSW 2000
Toll Free Number: 1800 675 229
www.pfizermedinfo.com.au

9. DATE OF FIRST APPROVAL

28 July 2014

10. DATE OF REVISION

26 April 2023

Summary Table of Changes

Section changed	Summary of new information
4.4	Added statement “Lack of efficacy or seizure worsening has been reported in patients with epilepsy associated with SCN8A mutations.”.
4.8	Addition of rare cases of OCD development in patients with underlying history or psychiatric disorders.

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