Description

Title of Invention

Composition for treating pain

Technical Field

The present invention relates to a composition for relieving or treating pain, the composition comprising a gene encoding glutamate decarboxylase and a gene encoding an anti-inflammatory cytokine; and a method for relieving or treating pain by using the composition.

Background Art

The term “pain” used by the International Association for the Study of Pain is defined as “actual or potential tissue damage or an unpleasant sensory and emotional experience associated therewith.” Pain protects parts of the damaged body during the healing of the damage from the damage occurrence and motivates a human being to avoid similar experiences in the future. Most pain is relieved gradually if the cause of stimulus is removed, but sometimes the pain persists even though the damaged site has clearly healed as the stimulus has disappeared, or the pain develops in a state where no irritation, damage or disease has occurred.

Neuropathic pain is a type of non-malignant chronic pain that is induced by abnormality of a nerve, a spinal cord or a brain and is assumed that 1% or more of the population is suffering therefrom. The most common causes of neuropathic pain are trauma, metabolic and ischemic disorders, etc., which cause pathological nerve impulses to be transmitted to the brain through the spinal cord, resulting in pain occurrence. Neuropathic pain can be classified into peripheral neuropathic pain and central neuropathic pain depending on the location affected.

If such neuropathic pain persists for a long period of time, it may lead to mental

pain as well as physical pain, and thus, the life quality of a patient is likely to decline. Therefore, active treatment for pain relief should be carried out. Currently, as the pain itself is recognized as a disease and interests in pain is spreading, demand for analgesics is expected to increase steadily in the future. Mainly, analgesics such as acetylsalicylic acid, ibuprofen, and acetaminophen are widely used in current pain treatments. If aspirin, whose main ingredient is acetylsalicylic acid, is used for analgesic purposes, a high dose of at least 500 mg should be administered. However, since aspirin is a non-steroidal anti-inflammatory analgesic (NSAIDs) and interferes with the production of gastric mucosa by blocking the enzyme (COX-1) that promotes the production of prostaglandin which plays a role in protecting gastric mucosa, the stomach can be easily damaged by gastric acid and gastrointestinal bleeding can easily occur. Further, since aspirin prevents thrombus formation, it can cause bleeding. Ibuprofen is also a non-steroidal anti-inflammatory analgesic ingredient, and therefore, it can cause gastric disturbances as well. In case of analgesics whose main ingredient is acetaminophen such as Tylenol, since acetaminophen is metabolized mostly in the liver, the liver may be damaged. Therefore, there are safety issues to lower its maximum dose, etc. In addition, long-term use of the above-mentioned analgesics often lead to resistance and loss of efficacies even if they are efficacious in the early stage, and specifically in case of neuropathic pain, there is a problem that the nonsteroidal anti-inflammatory agent is not effective even in the maximum dose for each patient, and thus high-dose administration for short term is prescribed. Therefore, the development of a new analgesic for neuropathic pain which exhibits excellent analgesic efficacy at low dose without side effects is urgently required.

Currently, several new substances are being developed as analgesics for neuropathic pain. Recently, sodium channel blockers has been developed, but they are mostly in the form of small molecules and have low selectivity to certain isoforms. Further, they show side effects such as cardio-toxicity, motor impairment, etc., and thus, more research in the future is necessary. As for a gene therapeutic agent, Periphagen

Holdings Inc. has developed a therapeutic agent in which a gene encoding enkephalin, an opioid peptide, was introduced into herpes simplex virus (HSV) gene carrier. However, in a clinical trial, the problem of declining in its analgesic efficacy has been found, and thus, its progression was halted at phase 2 study. HSV had the advantage of delivering genes to peripheral nerves even when subcutaneously administered, but, in fact, gene delivery efficiency is inferior and it seems to have difficulty in suppressing pain with only enkephalin, an opioid peptide.

Disclosure of Invention

Technical Problem

An example of the present invention relates to a composition for relieving or treating pain, which comprises a gene encoding glutamate decarboxylase (GAD) and a gene encoding an anti-inflammatory cytokine.

An additional example of the present invention is to provide a method for relieving or treating pain comprising administering a gene encoding GAD and a gene encoding an anti-inflammatory cytokine to a subject in need thereof.

Solution to Problem

The present invention provides a pharmaceutical composition for relieving or treating pain, which comprises a gene encoding glutamate decarboxylase (GAD) and a gene encoding an anti-inflammatory cytokine, and a method for relieving or treating pain comprising administering the same to a subject in need thereof.

Advantageous Effects of Invention

A pharmaceutical composition of the present invention can exhibit analgesic effect with only a small amount of gene delivery, and the pain-relieving efficacy can be observed even with a smaller amount of gene delivery as compared to single administration. GABA, a product of the GAD gene, has the efficacy of blocking pain

signal transduction, but excessive amount of it can cause symptoms such as itching, dizziness, drowsiness, etc., as well as side effects such as increased heartbeat rate or respiration rate. IL-10 is known to be a cytokine that exhibits anti-inflammatory effect, but side effects such as reducing RBC level, etc., were observed when high dose was used systemically. On the other hand, a pharmaceutical composition of the present invention exhibits excellent analgesic efficacy even with a smaller dose by employing co-administration the combination of GAD and IL-10 as compared to single administration, and thus, it shows the synergistic efficacy of lowering conventional side effects and toxicity by low dose administration.

Brief Description of Drawings

Fig. 1 shows a vector map of the plasmid pAAV-hGAD65 used for the production of recombinant adeno-associated viruses.

Fig. 2 shows a vector map of the plasmid pAAV-rIL-10 used for the production of recombinant adeno-associated viruses.

Fig. 3 shows a vector map of the plasmid pAAV-rIL-4 used for the production of recombinant adeno-associated viruses.

Fig. 4 is a diagram confirming the expression level of each protein by Western blot, where adeno-associated viruses respectively introduced with GAD65, IL-10 and IL-4 genes were prepared, and then 293T cells, a human embryonic kidney cell line, were treated with the viruses, and cells or culture media were collected after 48 hours.

Fig. 5 illustrates the expression of GABA by a recombinant adeno-associated virus AAV-hGAD65, which is a diagram showing GABA levels in the media measured by ELISA, where 293T cells, a human embryonic kidney cell line, were treated with AAB-GAD65, and the culture media were collected after 48 hours. Two identical samples were prepared separately for each experiment group, and the bar represents the value for each sample.

Fig. 6 shows the results of comparing the efficacies of co-administration of AAV-

GAD65 and AAV-IL-10 with gabapentin administration, which is a graph confirming the difference in synergistic efficacies of co-administration of AAV-GAD65 and AAV-IL-10 as compared to gabapentin used as a neuropathic pain reliever in the market.

Fig. 7 illustrates efficacies of AAV-GAD65 and AAV-IL-10 depending on combination composition ratios thereof. Particularly, it is a graph showing the synergistic effects in animal behavior analysis with the combination composition ratios of AAV-IL-10 to AAV-GAD of 1: 1, 1: 5, 1: 30.

Fig. 8 is a graph showing the synergistic effects when AAV-GAD65 and AAV-IL-10 were co-administered at 1: 10 and 1: 30 by transforaminal epidural injection.

Fig. 9 shows the results of comparing the efficacies of AAV-GAD65 and AAV-IL-10 with AAV-GAD65 and AAV-IL-4, which illustrates the synergistic effects in animal behavior analysis when IL-10 and IL-4 were respectively combined with GAD65 for use.

Best Mode for Carrying out the Invention

Hereinafter, the present invention will be described in detail.

In one example of the present invention, a gene encoding GAD and a gene encoding an anti-inflammatory cytokine are provided in a form of being contained in a carrier, and the carrier includes viral vectors and non-viral vectors such as a plasmid, liposome, or the like.

The gene encoding GAD may be operably contained in a first vector, and the gene encoding an anti-inflammatory cytokine may be operably contained in a second vector.

The viral vector may be at least one selected from the group consisting of adenovirus, adeno-associated virus, herpes simplex virus, lentivirus, retrovirus and poxvirus.

A carrier containing a gene encoding GAD according to the present invention (e.g., a first vector) and a carrier containing a gene encoding an anti-inflammatory cytokine

(e.g., a second vector) may have a virus titer-based mixing ratio per unit volume of 1: 1 to 1: 100, 1: 1 to 1: 80, 1: 1 to 1: 60, 1: 1 to 1: 40, 1: 1 to 1: 20, 1: 1 to 1: 10, 1: 3 to 1: 100, 1: 3 to 1: 80, 1: 3 to 1: 60, 1: 3 to 1: 40, 1: 3 to 1: 20, or 1: 3 to 1: 10, more preferably 1: 1 to 1: 50, and most preferably 1: 5 to 1: 30.

A pharmaceutical composition of the present invention can exhibit analgesic effect with only a small amount of genes or carriers containing the same. The composition of the present invention consists of a vector containing a gene encoding GAD and a vector containing an anti-inflammatory action gene in neural tissues, and the pain-relieving or treating efficacy can be achieved with a smaller amount as compared to single administration by co-administering substances having different analgesic mechanisms. Accordingly, since a composition of the present invention uses a small amount of genes or carriers containing the same, synergy of superior analgesic efficacies is shown while lowering toxicity.

According to an example of the present invention, the first vector and the second vector may be adeno-associated viruses. The adeno-associated virus is not limited to a specific serotype, and preferably, it may be any one of AAV1 to AAV5.

GAD according to the present invention is an enzyme which decarboxylates glutamate to produce GABA (gamma-aminobutyric acid). The gene encoding GAD applicable to the present invention may be one of GAD65 and GAD67, which are two isoforms. The GAD65 may be a human or rat protein or a gene encoding the same, and specific example thereof may consist of the amino acid sequence of SEQ ID NO: 1 of NCBI accession no. NM_000818, and also may consist of the base sequence of SEQ ID NO: 2 or SEQ ID NO: 3. The GAD67 may be a human or rat protein or a gene encoding the same, and specific example thereof may consist of the amino acid sequence of SEQ ID NO: 4 of NCBI accession no. NM_000817, and also may consist of the base sequence of SEQ ID NO: 5.

In a pharmaceutical composition according to the present invention, the inflammatory cytokine may be interleukin-10 (IL-10), and synergistic pain-relieving

efficacy is exhibited by co-administration of IL-10 and GAD65.

The IL-10 is one of anti-inflammatory cytokines and is also known as a cytokine synthesis inhibitory factor (CSIF). IL-10 belongs to the class II cytokine and is a homodimer consisting of two subunits of 178 amino acids in length. IL-10 serves the function of inhibiting the activity of NK (natural killer) cells in an immune response, and is involved in signal transduction by forming a complex with the IL-10 receptor. IL-10 may be a human or rat protein or a gene encoding the same, and specific example thereof may consist of the amino acid sequence of SEQ ID NO: 6 of NCBI accession no. NM_012854 or SEQ ID NO: 9 of NCBI accession no. NM_000572, and also may consist of the base sequence of SEQ ID NO: 7, SEQ ID NO: 8 or SEQ ID NO: 10.

The base sequences of the gene encoding GAD and/or the gene encoding IL-10 of the present invention include mutants thereof, which may be base sequences modified by codon optimization for rats or humans. Specifically, the base sequences having sequence homology of at least 60%, preferably 70% or more, more preferably 80% or more, even more preferably 90% or more, most preferably 95% or more are included, where the “sequence homology %” is identified by comparing two optimally arranged sequences and comparison regions, and a part of the sequences in the comparison region may include addition or deletion (i.e., gap) as compared to a reference sequence (not including addition or deletion) regarding the optimal arrangements of the two sequences.

The present invention also provides a method for relieving and/or treating pain comprising administering a therapeutically effective amount of the pharmaceutical composition to a patient in need of relieving and/or treating pain. The above method may further comprise, prior to the administering step, determining the patient as a patient in need of relieving and/or treating pain. The term “therapeutically effective amount” may depend on the amount of an active gradient to achieve a desired efficacy, pain relief and/or therapeutic efficacy.

The pain according to the present invention may include nociceptive pain, psychogenic pain, inflammatory pain associated with tissue damage and immune cell infiltration, pathological pain which is a disease state induced by damage to the nervous system or its abnormal function (dysfunctional pain such as fibromyalgia, irritable bowel syndrome, tension headache), etc. Also, the pain may include back pain distinguished anatomically, such as: neck pain, middle back pain, lower back pain, or tailbone pain. In addition, the pain may include pain such as neuropathic pain, migraine, etc. Neuropathic pain can result from damage or diseases that affect the somatosensory system. Neuropathic pain may be associated with an abnormal sensation called dysesthesia, and with allodynia in which pain sensation is evoked even with painless stimulation. Also, the neuropathic pain may also be a continuous and/or intermittent (seizure) factor. The latter is linked to electric shock in the figurative sense. General characteristics include being hot or cold, pins and needles, numbness, and itching.

In contrast, nociceptive pain is often expressed as “ache”. In addition, migraine is a chronic disorder that is associated with a number of autonomic nervous system symptoms and causes headaches of ordinary to severe intensities. The precise mechanisms of these migraines have not been clarified yet. The basic theory is related to the increased excitability of the cerebral cortex and the abnormal regulation of pain nerve cells in the trigeminal nucleus of the brainstem.

As a specific example, pain may be at least one selected from the group consisting of neuropathic pain, cancer pain, postoperative pain, trigeminal neuralgia, idiopathic pain, diabetic neuropathic pain, migraine, etc. As another specific example, the pain may not be a muscle spasm associated with lumbago.

Preferably, a composition of the present invention may be used for relieving or treating neuropathic pain or chronic cancer pain. The term “relieving or treating” refers to any action that alleviates or improves pain symptom by administering a composition of the present invention.

An additional example of the present invention relates to a method for relieving or

treating pain comprising administering a gene encoding GAD and a gene encoding an anti-inflammatory cytokine to a subject in need thereof. The subject may be a mammal including a human, or a cell and/or tissue isolated from a mammal including a human. Also, the subject may be a non-human animal, and the term "non-human animal" includes vertebrates such as mammals and non-mammals, for example, primates except humans, sheep, dogs, cats, horses, cows, chickens, amphibians, reptiles, etc.

The therapeutically effective amount and administration route of a pharmaceutical composition of the present invention can be appropriately adjusted in consideration of a condition of the patient, a desired efficacy, and the like by those of ordinary skill in the art. For example, a composition according to the present invention may be provided in the form of an injection, and may include, for example, nerve injection, subcutaneous injection, intramuscular injection, or gene gun injection.

Mode for the Invention

Hereinafter, the present invention is explained in detail by Examples, but the following Examples are intended to further illustrate the present invention without limiting its scope.

<Example 1> Preparation and property analysis of recombinant adeno-associated viruses

The adeno-associated viruses required for the present invention were prepared and produced based on the AAV helper-free system (Agilent, USA).

A. Preparation of pAAV-hGAD65

To prepare pAAV-hGAD65 of Fig. 1, the CMV promoter region of pJDK-rGAD65 [Lee B et al., Gene Ther, 12: 1215-1222 (2005)] was amplified by PCR and then introduced into pGEM-T (Promega, USA), to prepare pGEM-T-CMV. The primer

sequences used for the amplification of CMV promoter are as follows.

F-JDK (SEQ ID NO: 16): 5'-TTCGGCCGTCGAGGAGCTTGGCCCATTG-3'

R-JDK (SEQ ID NO: 17):

5'-GACGTCGACCTAGCTAGCGAATTCGGGGCCGCGGAG-3'

The GAD65 gene was prepared by codon-optimization to fit for humans based on the human GAD65 sequence having the amino acid sequence of SEQ ID NO: 1 (NCBI NM_000818) and synthesizing the base sequence of SEQ ID NO: 3 (Bioneer, Korea). The hGAD65 gene introduced into pGEM-T was treated with NheI and SalI to obtain a 1.7 Kb DNA fragment, which was ligated to a 3.7 Kb DNA fragment obtained by treating pGEM-T-CMV with NheI and SalI, to complete pGEM-T-CMV-hGAD65.

SV40pA was amplified by performing PCR using pCI (Invitrogen, USA) as a template, followed by treatment with ClaI and SalI, to obtain a 222 bp DNA fragment. The above fragment was ligated to a 5.4 Kb DNA fragment prepared by cutting pGEM-T-CMV-hGAD65 with ClaI and SalI, to finally prepare pGEM-T-CMV-hGAD65-SV40pA. The primer sequences used for the amplification of SV40pA are as follows.

F-SV40pA (SEQ ID NO: 18):

5'-CCATCGATCAGACATGATAAGATACATTGATGAG-3'

R-SV40pA (SEQ ID NO: 19):

5'-GACGTCGACGCGGCCGCTACCACATTTGTAGAGGTTTTACTTG -3'

The ampicillin-resistance gene in pAAV-MCS (Agilent, USA) was replaced with kanamycin-resistance gene for the preparation of adeno-associated virus vectors. The kanamycin-resistance gene was amplified by PCR using pET-28(a) (Novagen, USA) as a template, and the amplified 816 bp kanamycin-resistance gene was ligated to pGEM-T, to prepare pGEM-T-Kan^r. The primer sequences used for the amplification of kanamycin-resistance gene are as follows.

F-Kan (SEQ ID NO: 20): 5'-AGGCGCCATGAGCCATATTCAACGGGAA-3'

R-Kan (SEQ ID NO: 21): 5'-TTCATGATTAGAAAAACTCATCGAGCATC-3'

For the introduction of the kanamycin-resistance gene, SpeI and EcoRV sites were

respectively generated at the front and back of the ampicillin-resistance gene in pAAV-MCS by mutagenesis, and treated with SpeI and EcoRV, which was then ligated to the DNA fragment obtained by cutting the pGEM-T-Kan^r prepared above with NheI and EcoRV, to prepare pAAV-MCS-Kan^r.

The prepared pAAV-MCS-Kan^r was treated with NotI and BamHI, which was then ligated to a 2.7 Kb DNA fragment obtained by cutting pGEM-T-CMV-hGAD65-SV40pA with EagI and PvuI, to prepare pssAAV-GAD65.

In order to introduce the GAD65 expression cassette into pVAX1 (Invitrogen, USA), BamHI site was generated at the back of bGHpA by mutagenesis, which was then cut with MluI and NheI, to prepare DNA fragments. The LITR and CMV promoter regions were amplified by PCR using the pssAAV-GAD65 as a template, and cloned into pGEM-T easy (Promega, USA), which were then cut with AscI and NheI, and ligated to the pVAX1 vector prepared above, to prepare pVAX1-LITR-CMV. The primer sequences used for the amplification of LITR and CMV promoter regions are as follows.

F-ITR (SEQ ID NO: 22): 5'-ATGGCGCGCCCCTGGCCTTTTGCTGGCC-3'

R-JDK (SEQ ID NO: 17):

5'-GACGTCGACCTAGCTAGCGAATTCGGGGCCGCGGAG-3'

The pVAX1-LITR-CMV was prepared as a DNA fragment by cutting with NotI and NheI, and ligated to the DNA fragment prepared by cutting the pssAAV-GAD65 with Eagl and Nhel, to prepare pVAX1-LITR-CMV-hGAD65-SV40pA.

The pVAX1-LITR-CMV-hGAD65-SV40pA was cut with HpaI and BamHI, and then ligated to the DNA fragments obtained by treating the pGEM-T easy-SV40pA-RITR, which had been amplified by PCR using pssAAV-GAD65 as a template and cloned into pGEM-T easy, with Hpal and BamHI, to complete pVAX1-LITR-CMV-hGAD65-SV40pA-RITR (hereinafter, abbreviated as “pAAV-GAD65”). The primer sequences used for the amplification of SV40pA and RITR regions are as follows.

F-SV40pA (SEQ ID NO: 18):

5'-CCATCGATCAGACATGATAAGATACATTGATGAG-3'

R-ITR (SEQ ID NO: 23): 5'-ATGGATCCGCTAGTAAATACCGCATCAG-3'

The vector map of pAAV-hGAD65 is shown in Fig. 1.

B. Preparation of pAAV-rIL-10

pAAV-rIL-10 was prepared by a similar method to pAAV-hGAD65. Rat IL-10 gene was prepared by codon-optimization to fit for rats based on rat-derived base sequence (NCBI NM_012854) having the amino acid sequence of SEQ ID NO: 6 and synthesizing a gene having the base sequence of SEQ ID NO: 8 (Bioneer, Korea). The rIL-10 genes were amplified by PCR using the rat IL-10 genes introduced into pGEM-T easy as a template, and then treated with NheI and SalI to obtain a 0.5 Kb DNA fragment, which was then ligated to a 3.7 Kb DNA fragment obtained by cutting the pGEM-T-CMV with NheI and SalI, to prepare pGEM-T-CMV-rIL-10. The primer sequences used for the amplification of rIL10 is as follows.

F-rIL-10 (SEQ ID NO: 24): 5'-CCGCTAGCGCCACCATGCCT-3'

R-rIL-10 (SEQ ID NO: 25):

5'-GACGTCGACGCCATCGATGGCTTAATTAATCAATTCTTC-3'

SV40pA was amplified by performing PCR using pCI as a template, followed by treatment with NotI and SalI to obtain a 222 bp DNA fragment. The above fragment was ligated to a 4.2 Kb DNA fragment prepared by cutting pGEM-T-CMV-rIL-10 prepared above with ClaI and SalI, to prepare pGEM-T-CMV-rIL-10-SV40pA. The primer sequences used for the amplification of SV40pA are as follows.

F-SV40pA (SEQ ID NO: 18):

5'-CCATCGATCAGACATGATAAGATACATTGATGAG-3'

R-SV40pA (SEQ ID NO: 19):

5'-GACGTCGACGCGGCCGCTACCACATTTGTAGAGGTTTTACTTG -3'

A 1.6 Kb DNA fragment was obtained by treating pGEM-T-CMV-rIL-10-SV40pA with EagI, and then ligated to the DNA fragment prepared by treating pAAV-MCS-

Kan^r with NotI and BamHI, to prepare pssAAV-CMV-rIL-10-SV40pA (hereinafter, abbreviated as “pAAV-rIL-10”). The vector map of pAAV-rIL-10 is shown in Fig. 2.

C. Preparation of pAAV-rIL-4

The rat IL-4 gene was prepared by codon-optimization to fit for rats based on the rat-derived base sequence (NCBI NM_201270) having the amino acid sequence of SEQ ID NO: 11 and synthesizing a gene having the base sequence of SEQ ID NO: 13 (Bioneer, Korea). The rIL-4 genes introduced into pGEM-B1 (Bioneer, Korea) were treated with NheI and NotI to obtain a 0.5 Kb DNA fragment. The above fragment was ligated to a 3 Kb DNA fragment prepared by treating pAAV-hGAD65 with NheI and NotI, to prepare pssAAV-CMV-rIL-4-SV40pA (hereinafter, abbreviated as "pAAV-rIL-4"). The vector map of pAAV-rIL-4 is shown in Fig. 3.

D. Property analysis of recombinant adeno-associated viruses

The three types of plasmids (pAAV-hGAD65, pAAV-rIL-10 and pAAV-rIL-4) prepared above were respectively transfected into 293T cells, a human embryonic kidney cell line, with pHelper and pRC using PEI (Polysciences, USA). Herein, pRC5 into which the capsid gene of AAV serotype 5 was introduced was used for hGAD65, while pRC1 into which the capsid gene of AAV serotype 1 was introduced was used for rIL-10 and rIL-4. The transfected cells were cultured in a 37°C incubator, collected after 48 hours, and subjected to 3 cycles of freezing and thawing to obtain each crude virus.

In order to confirm the protein expression of the recombinant adeno-associated viruses delivered to the cells, 293T cells, a human embryonic kidney cell line, were respectively treated with crude viruses AAV5-hGAD65, AAV1-rIL-10 and AAV1-rIL-4, the protein expression was confirmed by Western blot. Specifically, 8 x 10^5 293T cells were aliquoted into T25 flasks, and each flask was treated with 700 μL of crude viruses on the next day, followed by culturing in a 37°C incubator. After 48 hours, the cells and

the culture media were harvested separately, and the cells were dissolved with a solubilizing agent and the culture media were concentrated with amicon (Merck Millipore, Germany). The prepared samples were treated with the antibodies to GAD65 (Cell signaling, USA), IL-10 (Santa Cruz, USA) and IL-4 (Santa Cruz, USA), respectively, and subjected to Western blot. The results are shown in Fig. 4.

Fig. 4 is a diagram showing the expression of each protein by performing Western blot analysis of the cell lysates of 293T cell line, a human embryonic kidney cell line, treated with AAV5-hGAD65, AAV1-rIL-10 or AAV1-rIL-4. By confirming that a target protein was expressed in every case, it was confirmed that there was no problem in the structure and property of the recombinant adeno-associated viruses used in the experiment.

In order to confirm that GABA is produced by AAV5-hGAD65, the culture media of the cells treated with AAV5-GAD65 were collected under the same condition as that for sample preparation for Western blot, and subjected to GABA ELISA (LDN, Netherland) analysis. The results are shown in Fig. 5. Two identical samples were prepared separately for each experiment group, and the bar represents the value for each sample. As a result, it was confirmed that GABA was secreted into the culture medium by GAD65 introduced into the cells by AAV5-hGAD65 viruses.

E. Preparation of recombinant adeno-associated viruses

Recombinant adeno-associated viruses were prepared and purified by KRcrogen (Korea) for animal efficacy experiments, and the preparation method is as follows.

Three types of plasmids (pAAV-hGAD65, pAAV-rIL-10, and pAAV-rIL-4) prepared above were respectively transfected into 293T cells, a human embryonic kidney cell line, using calcium phosphate method with pHelper and pRC. Herein, pRC5 into which the capsid gene of AAV serotype 5 was introduced was used for hGAD65, while pRC1 into which the capsid gene of AAV serotype 1 was introduced was used for rIL-10 and rIL-4. The transfected cells were cultured in a 37°C incubator,

and collected after 48 hours.

Then, only the bands containing viruses were isolated and purified through high-speed centrifugation depending on cesium concentration gradient, to obtain AAV5-hGAD65, AAV1-rIL-10 and AAV1-rIL-4. The titers of the produced viruses were measured using qPCR method established by the manufacturer.

<Example 2> Analgesic efficacy test of AAV-IL-10 and AAV-GAD65

A. Preparation of administration samples

30 minutes before the animal administration, the recombinant adeno-associated virus stored at -80°C were thawed at room temperature within 1 minute and mixed well by vortex. And Coomassie blue dye solution was prepared by mixing 10 mg of Coomassie blue in 1 mL of PBS well, and then filtering by syringe filters. 1 μL of AAV-GAD65 of 5.4 x 10^5 VG/μL, 1 μL of AAV-IL-10 of 1.8 x 10^7 VG/μL and 1 μL of 0.1% Coomassie blue dye were mixed under the calculation that each animal gets 3 μL in total. The samples were prepared twice as much as the amount required, and 3 μL of the sample was administered to each animal.

As a control group, Gabapentin was mixed in animals' drinking water 1 hour prior to administration, which was prepared in a concentration of 10 mg/mL.

B. Preparation of neuropathic pain animal model and sample administration

Male SD-rats of 180 to 200g were anesthetized with inhalation anesthesia, and then upper parts of the calves were incised, and both ends of the common peroneal nerve and tibial nerve were tied and knots were made by 7-0 suture at 0.5-1 cm intervals. The regions of the two nerve bundles between the knots were cut by scissors and the incision site was sutured. Two weeks later, *von Frey* filament test was performed to confirm pain induction, and then the test substance was administered (C.J. Woolf, *Pain* 87, 2000).

The test substance was administered to dorsal root ganglion (DRG). After

inhalation anesthesia of the pain animal model, rat's back at the lumbar spine from L3 to L5 was linearly incised to expose vertebral bones, and then a transverse process, one of the spinal projections, was exposed at the side of the exposure, and the L4 process covering the DRG in the fixed state was carefully separated under the Stereo zoom microscopic view by a rongeur such that the DRG is not damaged. The area around the DRG was manipulated so that the DRG which extends in an oblique line was exposed like grains of rice.

A hamilton syringe was connected to a polyethylene catheter, and 3 μL of the test substance was accurately collected. Then, the syringe was replaced with a 1 mL syringe for the administration. The rats were placed on a small animal stereotaxic instrument, and the sample was injected while confirming that the micro-needle was pricking the L4 DRG accurately under a surgioscope. Herein, it was confirmed that the sample containing dye did not leak out of the DRG and was well delivered to the inside of the DRG. After confirming that entire sample was delivered to the DRG, the syringe was separated from the DRG, and suturing was done, and the animals were recovered.

Gabapentin was orally administered with 3 mg/kg.

C. Observation of analgesic efficacy using *von Frey* filament test

The 50% up & down threshold method established by Dixon in 1992 was employed since it is a commonly known method. The method calculates threshold values depending on a predetermined patterns of pain responses with a total of 8 filaments whose N values were 0.4, 0.6, 1, 2, 4, 6, 8 and 15 g, respectively. Pain occurrence regions were searched through changing positions from the region of most lateral toe to the heel of the sole where pain has occurred.

Rats abruptly lift the soles and shrink or lick the soles when pain occurs. Accordingly, when pain occurring region was found, the surrounding area was pricked 5 times with the filament of the next step and if there were responses for 3 times or more, it was regarded as a pain response, and the rats were observed with the filament

of the next step. Patterns were recorded at every step. The pain patterns were recorded based on the pattern table established by S.R. Chaplan (Quantitative assessment of tactile allodynia in the rat paw. *Journal of Neuroscience Methods*, 1994) and the threshold values were calculated using it. The behavior analysis of the animal groups is performed by a blind method for 4 to 6 weeks, observed by at least 3 people, and the results of the recorded patterns are statistically processed to analyze the tendency of pain.

The results of pain-observation employing *von Frey* filament test where the pain animal model was administered with samples are shown in Fig. 6. Fig. 6 shows the results of comparing the efficacies between co-administration of AAV-GAD65 and AAV-IL-10 and gabapentin administration. When GAD65 and IL-10 were co-administered, statistically significant pain-relieving effect was observed as compared to the untreated control group (negative control), and the effect was found to be higher than that of Gabapentin.

<Example 3> Analgesic efficacy tests of AAV-IL-10 and AAV-GAD65

A. Preparation of administration samples

For the preparation of administration samples, rAAV5-GAD65 and rAAV1-rIL-10 which were prepared in Example 1 and stored in a frozen state were thawed, and samples were prepared in accordance with substantially the same method as the preparation method of administration samples in Example 2. Specifically, the single administration substance AAV-GAD65 or AAV-rIL-10 and the co-administration substances AAV-GAD65 and AAV-rIL-10 were diluted in PBS in a virus titer-based mixing ratio of 1:1, 1:5, or 1:30 as shown in Table 1, and 1 μL of 0.1% Coomassie blue dye was added to each sample under the calculation that each animal gets 3 μL. The samples were prepared twice as much as the amount required for the total population, and 3 μL of the sample was administered to each animal.

[Table 1]

Samples	Virus types and contents	
	AAV-GAD65	AAV-IL-10
Comparative Example 1 (GAD alone)	5.4×10^5 VG/ 2 μL	0
Comparative Example 2 (IL-10 alone)	0	1.8×10^7 VG/ 2 μL
Experimental Example 1 (1:1)	5.4×10^5 VG/ 1 μL	5.4×10^5 VG/ 1 μL
Experimental Example 2 (1:5)	5.4×10^5 VG/ 1 μL	2.7×10^6 VG/ 1 μL
Experimental Example 3 (1:30)	5.4×10^5 VG/ 1 μL	1.8×10^7 VG/ 1 μL

B. Observation of analgesic efficacy using *von Frey* filament test

Samples were administered to the pain animal models prepared by the same method as in Example 2, and pain was observed using a *von Frey* filament test, and the results are shown in Fig. 7.

Fig. 7 illustrates efficacies of AAV-GAD65 and AAV-IL-10 depending on composition ratios thereof. Particularly, compared to trace amounts of AAV-GAD65 and AAV-rIL-10 which showed no analgesic efficacy experiments with the mixing composition ratios of AAV-rIL-10 to AAV-GAD of 1:1 (Experimental Example 1), 1:5 (Experimental Example 2) and 1:30 (Experimental Example 3) exhibited synergistic efficacies in animal behavior analysis. As a result, the co-administration composition of AAV-GAD65 and AAV-rIL-10 according to the present invention showed an increasing pattern of the pain treatment efficacy as the mixing composition ratio of AAV-rIL-10 to AAV-GAD increased.

<Example 4> Analgesic efficacy tests of AAV-IL-10 and AAV-GAD65 using transforaminal epidural injection

A. Preparation of administration samples

30 minutes before the animal administration experiment, the reagents kept at -80°C were thawed at room temperature within 1 minute and mixed well by vortex. AAV-GAD65 and AAV-IL-10 were diluted in PBS to obtain the viral titers shown in Table 2. In order to administer 5 μL of the sample to each animal, the two virus diluted solutions were mixed half and half to obtain 1.5 times the volume required. Then, 5 μL of the sample was administered to each animal.

[Table 2]

Samples	Virus types and contents	
	AAV-GAD65	AAV-IL-10
Experimental Example1 (1: 10)	5.0×10^6 VG/ 2.5 μL	5.0×10^7 VG/ 2.5 μL
Experimental Example2 (1: 30)	5.0×10^6 VG/ 2.5 μL	1.5×10^8 VG/ 2.5 μL

B. Preparation of neuropathic pain model and sample administration

The neuropathic pain animal model was prepared by the same method as described in Example 2, and then the test substance was administered.

The test substance was administered by transforaminal epidural injection method at a position adjacent to the dorsal root ganglion (DRG). After inhalation anesthesia of the neuropathic pain animal model, rat's back at the lumbar spine from L3 to L5 was linearly incised to expose vertebral bones, and then, L4 transverse process, one of the spinal projections, was exposed at the side of the exposure. The rat was laid down sideways such that its side aspect could be seen from above, so that the L4 intervertebral foramen is visible.

A micro needle attached to the catheter was put into the prepared sample. A Hamilton syringe was connected to the opposite end of the catheter and pulled until reaching the marking of 5 μL to inject the sample into the catheter. After removing the

Hamilton syringe from the catheter, the region at 1 cm from the tip of the needle was gripped by Halsted-Mosquito. As L4 spine was gripped by forceps and pulled upward, the tip area of the needle fixed by Halsted-Mosquito Straight was placed around the L4 intervertebral foramen. The tip of the needle was inserted into the intervertebral foramen whose space was secured, and advanced until the needle reached a bent portion inside the intervertebral foramen, and the needle which had been gripped was released. After confirming that the needle is fixed, a 1 mL syringe was connected to the polyethylene catheter connected to the opposite side of the needle. The piston was gently pressed to slowly administer the diluted administration substance to the rat DRG surrounding area, followed by suturing, to complete the administration procedure. By the same method as described in Example 2, pain results employing the *von Frey* filament test were observed at 4 weeks after administration of the substance. The results are shown in Fig. 8.

Figure 8 shows that a mixture of AAV-GAD65 and AAV-IL-10 exhibits efficacy even when administered by the transforaminal epidural injection method. In addition, synergistic efficacy in animal behavior analysis was confirmed at the mixed composition ratio of AAV-GAD65 to AAV-IL-10 of 1: 10 (Experimental Example 1) and 1: 30 (Experimental Example 2).

<Example 5> Comparison of efficacies of AAV-GAD65 and AAV-IL-10 with AAV-GAD65 and AAV-IL-4

A pain animal model was prepared by substantially the same method as in Example 2, and the preparation procedure of the administration sample was the same as well. AAV1-rIL-4 described in Example 1 was thawed and prepared for use in animal experiments as follows.

30 minutes before animal DRG administration experiment, the reagents stored at -80°C were thawed at room temperature within 1 minute and mixed well by vortex. 10 mg of Coomassie blue was mixed well in 1 mL of PBS, and then, dyes filtered by

syringe filters were prepared. AAV-GAD65 and AAV-rIL-4 were diluted in PBS to obtain the virus titer-based mixing ratios shown in Table 3, and 1 μL of 0.1% Coomassie blue dye was added to each sample under the calculation that each animal gets 3 μL. The samples were prepared twice as much as the amount required for the total population, and 3 μL of the sample was administered to each animal.

[Table 3]

Samples	Virus types and contents		
	AAV-GAD65	AAV-IL-10	AAV-IL-4
Comparative Example 1	5.4×10^5 VG/ 2 μL	-	-
Comparative Example 2	-	1.8×10^7 VG/ 2 μL	-
Comparative Example 3	-	-	1.8×10^7 VG/ 2 μL
Comparative Example 4	5.4×10^5 VG/ 1 μL	-	1.8×10^7 VG/ 1 μL
Experimental Example 1	5.4×10^5 VG/ 1 μL	1.8×10^7 VG/ 1 μL	-

The pain results employing the *von Frey* filament test were observed, and the results are shown in Fig. 9. The Fig. 9 shows the results of comparing the efficacies of AAV-GAD65 and AAV-rIL-10 with AAV-GAD65 and AAV-rIL-4, which illustrates the synergistic efficacies comparatively appearing in animal behavior analysis when IL-10 and IL-4, cytokines having anti-inflammatory effects, were used in combination with GAD65, respectively. As shown in Fig. 9, the pain treatment efficacy was insignificant or not observed when GAD65, IL-10 or IL-4 was administered alone, and no significant analgesic efficacy was observed when GAD65 and IL-4 were co-administered as compared to the cases where GAD65 or IL-4 was administered alone. On the other hand, when GAD65 and IL-10 were co-administered, it was confirmed

that there was higher analgesic efficacy which was statistically significant than the other comparative examples. In particular, synergistic pain-relieving effect was observed, which was not shown when GAD65 and IL-4 were co-administered.

Claims:

Claim 1. A pharmaceutical composition for relieving or treating pain, which comprises a gene encoding glutamate decarboxylase (GAD) and a gene encoding interleukin-10 (IL-10).

Claim 2. The composition of claim 1, wherein the composition comprises a first vector operably containing a gene encoding GAD and a second vector operably containing a gene encoding IL-10.

Claim 3. The composition of claim 2, wherein the composition comprises a first vector containing a gene encoding GAD and a second vector containing a gene encoding IL-10 in a virus titer-based mixing ratio per unit volume of 1: 1 to 1: 50.

Claim 4. The composition of claim 3, wherein the vector is at least one viral vector selected from the group consisting of adenovirus, adeno-associated virus, herpes simplex virus, lentivirus, retrovirus and poxvirus.

Claim 5. The composition of claim 1, wherein the GAD is at least one selected from the group consisting of GAD65 and GAD67.

Claim 6. The composition of claim 1, wherein the GAD consists of the amino acid sequence of SEQ ID NO: 1 or SEQ ID NO: 4.

Claim 7. The composition of claim 1, wherein the gene encoding GAD consists of the base sequence of SEQ ID NO: 2, SEQ ID NO: 3 or SEQ ID NO: 5.

Claim 8. The composition of claim 1, wherein the IL-10 consists of the amino

acid sequence of SEQ ID NO: 6 or SEQ ID NO: 9.

Claim 9. The composition of claim 1, wherein the gene encoding IL-10 consists of the base sequence of SEQ ID NO: 7, SEQ ID NO: 8 or SEQ ID NO: 10.

Claim 10. The composition of claim 1, wherein the pain is nociceptive pain, psychogenic pain, inflammatory pain, or pathological pain.

Claim 11. The composition of claim 10, wherein the pain is neuropathic pain, cancer pain, postoperative pain, trigeminal neuralgia, idiopathic pain, diabetic neuropathic pain, or migraine.

Claim 12. The composition of claim 1, wherein the pharmaceutical composition further comprises a physiologically acceptable carrier.

Claim 13. The composition of claim 1, wherein the pharmaceutical composition is an injection.

Claim 14. A method for relieving or treating pain comprising administering a pharmaceutical composition according to any one of claims 1 to 13.

Claim 15. The method of claim 14, wherein the pain is nociceptive pain, psychogenic pain, inflammatory pain, or pathological pain.

Claim 16. The method of claim 15, wherein the pain is neuropathic pain, cancer pain, postoperative pain, trigeminal neuralgia, idiopathic pain, diabetic neuropathic pain, or migraine.