The evolution of brain imaging techniques over the last decade has been remarkable. Along with such technical developments, research into chronic pain has made many advances. Given that brain imaging is a non-invasive technique with great spatial resolution, it has played an important role in finding the areas of the brain related to pain perception as well as those related to many chronic pain disorders. Therefore, in the near future, brain imaging techniques are expected to be the key to the discovery of many unknown etiologies of chronic pain disorders and to the subjective diagnoses of such disorders. (Korean J Pain 2010; 23: 159-165)

Key Words: 
brain imaging, chronic pain.

INTRODUCTION

The ancient Greek philosopher Epictetus stated in his book, The Enchiridion, that "For death or pain is not formidable, but the fear of pain or death." [1]. Setting the philosophical interpretation of the statement aside and focusing on Epictetus' insight that the fear of 'pain' is greater than the fear of 'death', it becomes clear that throughout the ages pain has been one of the most distressing miseries that a human being may experience. There are two types of pain: acute pain and chronic pain. Chronic pain is that which brings agony to mankind from childhood to old age. According to a recent survey, 20% of the European population suffers from chronic pain [2]. In Korea, more than 10% of the adult population suffers from chronic pain disorder. It has become commonly accepted that the incidence may be substantially underestimated. In 2006, the second largest-selling pharmaceutical product category in Korea was analgesics [3]. Nearly 65% of people with chronic pain reported that pain interferes with their daily life [4]. In addition to the impairment of life functions, chronic pain has a high comorbidity rate. The majority of chronic pain sufferers have a greater incidence of other disorders, including mood disorders, anxiety disorders, and sleep disorders [5-10].

However, while chronic pain afflicts a considerable number of people, there is insufficient understanding and insight into its unique characteristics [11]. Moreover, although chronic pain is studied as a component of a number of research areas, such as anesthesiology and pain medi-
cine, anatomy, neurology, and psychiatry, thus far there has been no solid and objective indicator established for the diagnosis of pain. The fact that pain is a very subjective experience is one of the reasons for this. Brain imaging may serve as a viable solution to the subjectivity problem of pain, as brain imaging is non-invasive and facilitates both a structural and functional approach to understanding chronic pain [12]. Over the past ten years, numerous studies of chronic pain have been carried out using brain imaging techniques. Through those studies, pain researchers were able to establish a pain matrix, which is comprised of the brain areas related to pain perception. These areas include the primary somatosensory cortex (SI), secondary somatosensory cortex (S2), insula, anterior cingulate cortex (ACC), primary motor cortex, supplementary motor area (SMA), thalamus, basal ganglia, midbrain, cerebellum, prefrontal cortex (PFC), and the posterior parietal cortex [13–16]. Therefore, reviewing chronic pain studies based on brain imaging methods will hasten the standardization of the diagnosis of chronic pain and will provide directions for further study.

FUNCTIONAL IMAGING STUDIES

1. Functional Magnetic Resonance Imaging (fMRI)

The imaging method known as fMRI is one of the most commonly used imaging methods in chronic pain research. There are many chronic pain disorders of which the etiology is unknown due to a lack of understanding of the structural abnormalities and their association with different disorders. fMRI is a very useful non-invasive technique for obtaining information related to neural networks and their activities [17,18].

Fibromyalgia is a common chronic pain disorder. It is characterized by alldynia all over the body and a feeling of exhaustion with no specific cause. Fibromyalgia commonly accompanies other disorders, such as mood disorder or sleep disorder. Fibromyalgia studies are mostly focused on abnormal activities that occur in the central nervous system. Numerous studies have reported that fibromyalgia patients have distinctly more activity in the pain matrix compared to control groups. According to the latest research, predictions of pain and perceptions of pain both have a meaningful positive correlation with hyperactivity in the brain areas of the motor cortex and cingulate cortex; the patient group in this line of research showed distinct activity in the frontal and temporal areas [19]. Moreover, increased activity was noted in the medial frontal cortex, cerebellum, dorsal ACC, dorsolateral PFC, and claustrum, all of which are areas related to pain anticipation and attention and all of which have a significant correlation with pain catastrophizing [20]. The areas of the anterior and mid-cingulate cortex, middle frontal cortex, SMA, thalamus, anterior insula, and basal ganglia displayed more activity in fibromyalgia patients [21,22]. Overall, fibromyalgia patients showed increased neural activity in pain-related areas.

Chronic back pain is a widespread pain disorder that affects a broad range of the population. It has been estimated that nearly 80% of the human population has experienced chronic back pain at least once in their life [23]. However, the pathological causes of this type of pain remain unidentified. In this area of research, neuro-imaging techniques have been used to investigate the causes. According to Baliki et al. [24], chronic back pain influences the deactivation of the default mode network (DMN) during the resting state. It has also been reported that the posterior cingulate cortex (PCC) plays an important role as an affective component of pain mediation, as much as the ACC, which is known to be responsible for pain mediation [25]. In another study, the medial PFC showed significantly increased activity in chronic back pain patients [26].

Complex regional pain syndrome (CRPS) is a chronic pain disorder that accompanies sensory, motor, and autonomic dysfunctions. Its origin as well has yet to be identified. This lack of knowledge delays the proper type of treatment for CRPS patients [26–28]. Maihöfner et al. [26] observed activations in the S1 and S2 cortex, insula, PFC, and in the ACC during pin-prick stimulation of CRPS patients who experience hyperalgesia. They found that the S2 cortex is also involved in the processing of non-painful stimuli. Another report found that children and teenagers with CRPS showed distinct activation patterns in the central nervous system when stimulated with mechanical and thermal stimuli; especially noted was decreased activity during a painful state [29].

There are many other chronic pain studies involving patients with unidentified chronic pain. Molinen et al. [30] studied 10 patients who suffered severely from unknown chronic pain. They found that during a resting period, these patients showed abnormal temporal and spatial fluctuations and connectivity disturbances in the pain matrix,
particularly the lower insula and the ACC. Diabetic patients who suffered from neuropathic pain also displayed significantly different brain activity from healthy control subjects during the resting period [31]. Disturbances in the DMN of chronic pain patients have been noted in many studies [24,30,31]. Another report showed that when patients feel depressed, the activities of the PFC, subgenual ACC, and hippocampus are all more intense, as is the level of perceived pain [32]. Such studies give deeper insight into the high correlation between chronic pain and mood disorders.

2. Chemical imaging studies: magnetic resonance spectroscopy (MRS)

MRS allows us to explore not only the structural information but also the biochemical information of the brain. There are few MRS studies pertaining to chronic pain. A handful of studies suggest the important role of glutamate in chronic pain. Harris et al. [33] reported that the levels of glutamate and combined glutamate, both known to play an important role in pain neurotransmission, were significantly higher in the right posterior insula of fibromyalgia patients. They also found that glutamate and combined glutamate levels are negatively correlated with pain threshold. Moreover, glutamnergic abnormalities were found in the ACC and insula of migraine patients. Such abnormalities were suggested to be responsible for the chronic nature of the patients’ migraines [34]. There have also been reports that N-acetyl aspartate and glucose were decreased in the dorsolateral PFC of chronic back pain patients [35,36]. When such findings achieve more reliable congruence, accounting for this information may lead to more objective diagnoses of chronic patients.

**STRUCTURAL IMAGING STUDIES**

1. Voxel-Based Morphometry (VBM)

Using VBM, the volume of brain tissue can be measured. By comparing the gray matter volume of chronic pain patients to that of healthy controls, structural differences, if they exist, in the brains of pain patients can be estimated. Research on chronic pain using VBM includes a few conflicting results, but thus far, researchers generally agree that chronic pain patients have decreased gray matter volume in the regions considered as the pain matrix. Chronic tension-type headache patients showed an overall decrease in their gray matter volume in the pain matrix [37], while chronic back pain patients also showed reduced gray matter density in the bilateral dorsolateral PFC and right thalamus compared to healthy controls [38]. CRPS patients also showed overall decrease in gray matter volume. Gray matter reduction in the right insula, right ventromedial PFC, and right nucleus accumbens was particularly more severe compared to that in other regions [39]. Gray matter intensity in fibromyalgia patients was significantly reduced in the postcentral gyrus, amygdala, hippocampus, superior frontal gyrus, and anterior cingulate gyrus as well [40]. Burgmer et al. [41] also reported decreased gray matter volume in the PFC, amygdala, and ACC. A study of female fibromyalgia patients also found significantly decreased gray matter density in the left parahippocampal gyrus, bilateral mid/posterior cingulate gyrus, left insula, and medial frontal cortex [42]. Kim et al. [43] also reported decreased gray matter volumes in the bilateral insula, bilateral motor/premotor cortex, bilateral PFC, left dorsal ACC, right dorsal posterior cingulate cortex, right inferior and superior parietal cortex, and orbitofrontal cortex in migraine patients. Amputees who experience phantom limb sensations had reduced gray matter in the anterior and posterior cingulate regions, SMA, and midbrain [44]. However, other studies report increased gray matter volume in some brain regions, as well as reports of gray matter reduction. Chronic back pain patients showed substantial decreases in the somatosensory cortex and brainstem, whereas the volume of gray matter in the bilateral basal ganglia and left thalamus increased significantly [45]. Another report found that fibromyalgia patients had increased gray matter volumes in their left orbitofrontal cortex, left cerebellum and bilateral striatum with decreased gray matter volume in their right superior temporal gyrus and left posterior thalamus [46]. In addition, Teutsch et al. [47] observed a number of modulations, including an increase in gray matter in the middle cingulate cortex and somatosensory cortex when noxious stimuli were applied repetitively to healthy subjects. Although it is too soon to conclude anything regarding a tendency toward an increase in gray matter in chronic pain patients at this point, increased gray matter volumes were observed mostly in the left hemisphere.

2. Diffusion Tensor Imaging (DTI)

The DTI method provides quantitative information on
chronic pain processing in the central nervous system by monitoring the motions of water molecules. It can be an effective marker for the structural evolution of long-term disease [48]. Chronic pain studies using a DTI technique are not yet as prevalent as studies that utilize other imaging techniques. Using a DTI method, Rocca et al. [49] investigated normal–appearing brain tissue in migraine patients. They reported no significant differences in fractional anisotropy (FA) and mean diffusivity. Later in 2006, they investigated the influence of normal–appearing white matter and gray matter separately in migraine patients. They found a reduction in the mean diffusivity of the gray matter in migraine patients, whereas no significant difference was noted in the mean diffusivity of their white matter. Moreover, no distinct FA difference was noted in both the white and gray matter of these patients [50]. Lutz et al. [40] reported that white matter FA was decreased in the bilateral thalamus, bilateral insula and thalamocortical tracts, whereas it was increased in the postcentral gyrus, amygdala, hippocampus, superior frontal gyrus and anterior cingulate gyrus. They also suggested that the perception of both pain intensity and fatigue was associated with the white matter FA in certain regions of the pain matrix, implying its possible application in pain diagnosis. CRPS patients showed decreased white matter FA in left callosal fiber tract in lateral ACC [39]. If structural changes are consistently observed in patients, diagnosing chronic pain disorders and estimating the degree of suffering can be standardized.

**NETWORKS OF DISTINCT PAIN PROCESSES IN THE BRAIN**

Pain–related brain areas have different patterns of activity during the processing of pain with distinct characteristics. Related to the affective aspects of pain processing, areas such as the insula, inferior frontal gyrus, orbitofrontal cortex, ventrolateral and dorsolateral prefrontal cortex, ACC, and PCC show discriminative activity [18, 20,32,51,52]. The S1 and S2 areas as well as the insula are reportedly essential in the sensory processing of pain, and many feel that S2 is also important for affective processing [20,52–55]. Pain processing related to attention has been associated with significantly altered activity in the thalamus, insula, hippocampus, ACC, orbitofrontal cortex, dorsolateral prefrontal cortex, and posterior parietal cortex (Fig. 1) [20,53,55,56]. In addition, it is important to note that among these areas, the insula has been continually reported to be significantly active during all of the processes of pain. These distinctions in pain processing may be essential for treating chronic pain patients with distinct symptoms. Moreover, as these processes cover various functions of the central nervous system, multidisciplinary approaches will be critical.

**CONCLUSIONS**

For the past decade, brain imaging techniques have made remarkable progress [16] and have contributed to advances in chronic pain research. Overall, the fMRI studies report increased activities in pain patients’ pain matrix, regardless of disorders. There are some studies that reports increased volume of gray matter of chronic pain group, but most reports have agreed that gray matter volume in the chronic pain patient is decreased. Most fre-
### Table 1. Brain Imaging Studies on Chronic Pain

| Disease                  | Method       | Author(s)              | Increase                                                                 | Decrease                                                                 |
|--------------------------|--------------|------------------------|--------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Fibromyalgia             | fMRI         | Burgmer et al.          | Cingulate cortex, Frontal cortex                                         | Right thalamus                                                          |
|                          |              | Burgmer et al.          | Frontal cortex, Motor cortex, Cingulate cortex                           | None                                                                     |
|                          |              | Gracey et al.           | Primary / Ipsilateral secondary somatosensory cortex, Posterior cingulate gyrus, Anterior / Posterior cerebellum, Superior / Inferior frontal gyrus | None                                                                     |
|                          | MRS          | Pujol et al.            | Insula, Basal ganglia, Anterior cingulate cortex                         | Somatosensory cortices                                                  |
|                          | VBM          | Harris et al.           | Glutamate: Right posterior insula                                        | None                                                                     |
|                          | VBM/DTI      | Schmidt-Wilcke et al.   | None                                                                     | Bilateral striatum                                                      |
|                          |              | Lutz et al.             | DTI: Postcentral gyrus, Amygdala, Hippocampus, Superior frontal gyrus, Anterior cingulate gyrus | VBM: Postcentral gyrus, Amygdala, Hippocampus, Superior frontal gyrus, Anterior cingulate gyrus DTI: Thalamocortical tract, Insula |
| Chronic back pain        | fMRI         | Baliki et al.           | Medial prefrontal cortex                                                | None                                                                     |
|                          |              | Baliki et al.           | Medial prefrontal cortex, Amygdala, Posterior cingulate, Precuneus      | None                                                                     |
|                          | MRS          | Kobayashi et al.        | Posterior cingulate cortex, Anterior cingulate cortex                   | N-acetyl aspartate, Glucose, Dorsolateral prefrontal cortex             |
|                          | VBM          | Grachev et al.          | None                                                                     | Bilateral dorsolateral prefrontal cortex, Right thalamus                |
| Complex regional pain syndrome | fMRI        | Schmidt-Wilcke et al.   | Basal ganglia, Left thalamus                                            | Brain stem, Somatosensory cortex, Dorsolateral prefrontal cortex       |
|                          | VBM/DTI      | Geha et al.             | DTI: Ventromedial prefrontal cortex to Insula                           | VBM: Ventromedial prefrontal cortex, Anterior insula, Right nucleus accumbent, Orbitofrontal cortex DTI: Ventromedial prefrontal cortex to Basal ganglia |
| Chronic migraine         | fMRI         | Chiapparini et al.      | Right postcentral gyrus, Right inferior parietal lobule, Bilateral supramarginal gyrus | None                                                                     |
|                          | MRS          | Dichigans et al.        | Myo-inositol: Superior cerebellar vermis                                | N-acetyl aspartate, Glucose, Brain parenchyma fraction, Superior cerebellar vermis |
| DTI                      |              | Rocca et al.            | None                                                                     | Gray matter mean diffusivity                                            |

Frequently observed pain-related brain regions that showed abnormal brain function or structure were insula, thalamus, cingulate cortex, basal ganglia and frontal cortex (Table 1).

With these imaging methods, researchers have been able to understand the functional and structural mechanisms of chronic pain. However, a number of fundamental questions remain unanswered, and multitudes still suffer from chronic pain without clear etiological information.

Although pain researchers are now much more conversant in their comprehension of chronic pain compared to where they were years ago, more insight is required to unravel the nature of chronic pain and to apply the findings so as to treat or diagnose those who suffer from chronic pain. Therefore, in chronic pain research, active multidisciplinary approaches are necessary to get to the core of the mechanisms of chronic pain.
REFERENCES

1. Epictetus. Discourses of epictetus. Sioux Falls: NuVision Publications, LLC 2006, p 98.
2. Breivik H, Collett B, Ventafrida V, Cohen R, Gallacher D. Survey of chronic pain in Europe: prevalence, impact on daily life, and treatment. Eur J Pain 2006: 10: 287–333.
3. Kim E. KHD statistics brief, vol. 1, Seoul, Korea Health Industry Development Institute 2008, p 5.
4. Gustorf B, Dorner T, Likar R, Grisold W, Lawrence K, Schwarz F, et al. Prevalence of self-reported neuropathic pain and impact on quality of life: a prospective representative survey, Acta Anaesthesiol Scand 2008: 52: 132–6.
5. Campbell LC, Clauw DJ, Keele FJ. Persistent pain and depression: a biopsychosocial perspective. Biol Psychiatry 2003: 54: 399–409.
6. Nicholson B, Verma S. Comorbidities in chronic neuropathic pain. Pain Med 2004: 5(Suppl 1): S9–S27.
7. Vogt BA. Pain and emotion interactions in subregions of the cingulate gyrus, Nat Rev Neurosci 2005: 6: 533–44.
8. Broggi G. Pain and psycho-affective disorders, Neurosurgery 2008: 62(Suppl 3): 901–19.
9. Maletic V, Rason C. Neurobiology of depression, fibromyalgia and neuropathic pain, Front Biosci 2009: 14: 5291–338.
10. Turk DC, Audelette J, Levy RM, Mackey SC, Stanos S. Assessment and treatment of psychosocial comorbidities in patients with neuropathic pain, Mayo Clin Proc 2010: 85(3 Suppl): S42–50.
11. Apkarian AV, Baliki MN, Geha PY. Towards a theory of chronic pain, Prog Neurobiol 2009: 87: 81–97.
12. Tracey I. Neuroimaging of pain mechanisms, Curr Opin Support Palliat Care 2007: 1: 109–16.
13. Ochsner KN, Zaki J, Hanellin J, Ludlow DH, Knerim K, Ramachandran T, et al. Your pain or mine? Common and distinct neural systems supporting the perception of pain in self and other, Soc Cogn Affect Neurosci 2008: 3: 144–60.
14. Tracey I. Imaging pain, Br J Anaesth 2008: 101: 32–9.
15. May A. Neuroimaging: visualising the brain in pain, Neurol Sci 2007: 28(Suppl 2): S101–7.
16. Sellert F, Mahölnner C. Central mechanisms of experimental and chronic neuropathic pain: findings from functional imaging studies, Cell Mol Life Sci 2009: 66: 375–90.
17. Chiapparini L, Grazzi L, Ferraro S, Mandelli ML, Usai S, Andrask G, et al. Functional–MRI evaluation of pain processing in chronic migraine with medication overuse, Neurol Sci 2009: 30(Suppl 1): S71–4.
18. Baliki MN, Chialvo DR, Geha PY, Levy RM, Harden RN, Parrish TB, et al. Chronic pain and the emotional brain: specific brain activity associated with spontaneous fluctuations of intensity of chronic back pain, J Neurosci 2006: 26: 12165–73.
19. Burgmer M, Pogatzki-Zahn E, Gaubitz M, Stüber C, Wessoleck E, Heuft G, et al. Fibromyalgia unique temporal brain activation during experimental pain: a controlled fMRI Study, J Neural Transm 2010: 117: 123–31.
20. Gracely RH, Greiser ME, Giesecke T, Grant MA, Petzke F, Williams DA, et al. Pain catastrophizing and neural responses to pain among persons with fibromyalgia, Brain 2004: 127: 835–43.
21. Burgmer M, Gaubitz M, Konrad C, Weneger M, Hilgart S, Heuft G, et al. Decreased gray matter volumes in the cingulo–frontal cortex and the amygdala in patients with fibromyalgia, Psychosom Med 2009: 71: 566–73.
22. Pujol J, López–Sotol M, Ortiz H, Vlanova JC, Harrison BJ, Yáñez C, et al. Mapping brain response to pain in fibromyalgia patients using temporal analysis of fMRI, PLoS One 2009: 4: e5224.
23. Andersson GB. Epidemiology of low back pain, Acta Orthop Scand Suppl 1998: 281: 28–31.
24. Baliki MN, Geha PY, Apkarian AV, Chialvo DR. Beyond feeling: chronic pain hurts the brain, disrupting the default–mode network dynamics, J Neurosci 2008: 28: 1398–403.
25. Kobayashi Y, Kurata J, Sekiguchi M, Kobukum M, Akaihizawa T, Chiba Y, et al. Augmented cerebral activation by lumbar mechanical stimulus in chronic low back pain patients: an fMRI study, Spine 2009: 34: 2431–6.
26. Mahölnner C, Forster C, Birkenfeld F, Neuđöfter B, Handwerker HO. Brain processing during mechanical hyperalgesia in complex regional pain syndrome: a functional MRI study, Pain 2005: 114: 93–103.
27. Ok SJ, Yang JY, Son JH, Jeong WJ, Lee YS, Kim WY, et al. Management of complex regional pain syndrome type 1 with total spinal block. Korean J Pain 2010: 23: 70–3.
28. Choi YS, Lee MG, Lee HM, Lee CJ, Jo JY, Jeon SY, et al. Epidemiology of complex regional pain syndrome: a retrospective chart review of 150 Korean patients, J Korean Med Sci 2008: 23: 772–5.
29. Lebel A, Becerra L, Wallin D, Moulton EA, Morris S, Pendse G, et al. fMRI reveals distinct CNS processing during symptomatic and recovered complex regional pain syndrome in children, Brain 2008: 131: 1854–79.
30. Malinen S, Vartianen N, Huhtschuk Y, Koskinen M, Ram–kumar P, Forss N, et al. Aberrant temporal and spatial brain activity during rest in patients with chronic pain, Proc Natl Acad Sci USA 2010: 107: 6493–7.
31. Cauda F, Sacco K, Duca S, Cocco D, D’Agata F, Geminiani GC, et al. Altered resting state in diabetic neuropathic pain, PLoS One 2009: 4: e4542.
32. Berna C, Leknes S, Holmes EA, Edwards RR, Goodwin GM, Tracey I. Induction of depressed mood disrupts emotion regulation neurocircuitry and enhances pain unpleasantness, Biol Psychiatry 2010: 67: 1083–90.
33. Harris RE, Sundgren PC, Craig AD, Krushenbaum E, Sen A, Napadow V, et al. Elevated insular glutamate in fibromyalgia
is associated with experimental pain, Arthritis Rheum 2009; 60: 3146–52.
34. Prescot A, Becerra L, Pendse G, Tully S, Jensen E, Har−
    greaves R, et al. Excitatory neurotransmitters in brain regions
    in interictal migraine patients, Mol Pain 2009; 5: 34.
35. Grachev ID, Fredrickson BE, Apkarian AV. Abnormal brain
    chemistry in chronic back pain: an in vivo proton magnetic
    resonance spectroscopy study. Pain 2000; 89: 7–18.
36. Grachev ID, Fredrickson BE, Apkarian AV. Brain chemistry
    reflects dual states of pain and anxiety in chronic low back
    pain, J Neural Transm 2002; 109: 1309–34.
37. Schmidt-Wilcke T, Leinisch E, Struube A, Kämpfe N,
    Draganski B, Diener HC, et al. Gray matter decrease in
    patients with chronic tension type headache. Neurology
    2005; 65: 1483–6.
38. Apkarian AV, Sosa Y, Sonty S, Levy RM, Harden RN, Parrish
    TB, et al. Chronic back pain is associated with decreased
    prefrontal and thalamic gray matter density. J Neurosci 2004;
    24: 10410–5.
39. Geha PY, Balki MN, Harden RN, Bauer WR, Parrish TB,
    Apkarian AV. The brain in chronic CRPS pain: abnormal
    gray-white matter interactions in emotional and autonomic
    regions. Neuron 2008; 60: 570–81.
40. Lutz J, Jäger L, de Quervain D, Krauseneck T, Padberg F,
    Wichnalek M, et al. White and gray matter abnormalities in
    patients with fibromyalgia: a diffusion-tensor and
    volumetric imaging study. Arthritis Rheum 2008; 58:
    3960–9.
41. Burgmer M, Pogatzki-Zahn E, Gaubitz M, Wessoleck E, Heuft
    G, Pfleiderer B. Altered brain activity during pain processing
    in fibromyalgia. Neuroimage 2009; 44: 502–8.
42. Kuchinad A, Schweinhardt P, Seminowicz DA, Wood PB,
    Chizh BA, Bushnell MC. Accelerated brain gray matter loss
    in fibromyalgia patients: premature aging of the brain? J
    Neurosci 2007; 27: 4004–7.
43. Kim JH, Suh SI, Seol HY, Oh K, Seo WK, Yu SW, et al.
    Regional grey matter changes in patients with migraine: a
    voxel−based morphometry study, Cephalalgia 2008; 28:
    598–604.
44. Draganski B, Moser T, Lummel N, Gänsbauer S, Bogdahn
    U, Haas F, et al. Decrease of thalamic gray matter following
    limb amputation. Neuroimage 2006; 31: 951–7.