

## Final Manuscript Approval External Inbox x

APICARE <apicare@yahoo.com>  
to me ▾

Dear Author,

Please have a final look at your copy edited manuscript. If any correction is required, please make it in red color. Please expedite, to allow us to proceed with the publishing process. Thanks.

Use facemask, observe social distancing and frequent hand washing.  
My humble prayers for good health and well-being of your family and friends.

Tariq H. Khan,  
Editor-in-Chief,  
APICAREHQ,  
25-E, Ibn-e-Sina Road, G-10/3,  
Islamabad (Pakistan)  
Cell: +92 321 5149709  
[www.apicareonline.com](http://www.apicareonline.com)



Mon, Apr 5, 2021, 1:54 PM



## NARRATIVE REVIEW

## PAIN MANAGEMENT

## Pathogenesis and management of pain in amyotrophic lateral sclerosis

Hanik Badriyah Hidayati<sup>1</sup>, Celine Anindytha Pranata<sup>2</sup>

**Author affiliations:**

- 1- Department of Neurology, Faculty of Medicine, Airlangga University/ Dr. Soetomo General Hospital, Surabaya, Indonesia.
- 2- Department of Neurology, Faculty of Medicine, Airlangga University, Surabaya, Indonesia.

**Correspondence:** Hanik Badriyah Hidayati; hanikhidayati@fk.unair.ac.id

### Abstract

Amyotrophic lateral sclerosis (ALS) or Lou Gehrig's disease is characterized by deadly progressive motor neuron disease and other neuronal cells death, which is featured by progressive paralysis and leads to advanced disability and mortality due to respiratory failure.<sup>1,2</sup> By the year of 2040, ALS is estimated to nearly double due to global population aging.<sup>3</sup>

Pain is one of the overlooked symptom, but widely complained by patients with ALS. It can arise at any stage of the disease; and the intensity of pain may increase with the course of the disease. The pain characteristic depends upon its pathogenesis in inducing pain such as nociceptive, neuropathic, or painful cramps. Pain intensity can be severe at an advanced stage of ALS thereby increasing the use of pain relievers and sedatives. It has been related to a declined functional status leading to a decreased quality of life and escalating the rate of depression. Management in ALS patients with complaints of pain differs according to the multifactorial character of pain.<sup>4,5</sup>

The different aspects of pain in ALS has not been much discussed. Therefore, this article will provide an overview about it.

**Key word:** Pain; Amyotrophic lateral sclerosis; ALS; Pathogenesis; Pain management

**Citation:** Hidayati HB, Pranata CA. Pathogenesis and management of pain in amyotrophic lateral sclerosis. *Anaesth. pain intensive care* 2021;25(2):236-243. DOI: 10.35975/apic.v25i2.1478

**Received:** 26 November 2020, **Reviewed:** 27 December 2021, **Accepted:** 21 February 2021

### 1. Introduction

Amyotrophic lateral sclerosis (ALS) is a rare neurodegenerative disease that implicates central and peripheral motor neurons. The patients succumb to the disease within 2–4 years from the onset. Clinically, ALS manifests as progressive loss of general muscle strength and dystrophy, which leads to respiratory muscle paralysis due to the bulbar or spinal levels onset.<sup>4,6</sup>

Pain is one of the indirect secondary conditions of ALS that can be as debilitating as those symptoms associated with the disease directly. It develops in almost 70% of the ALS patient during the progression

of the disease. The pain frequency is thought to increase with the disease progression.<sup>7</sup>

The identification of pain in patients with ALS should not be underestimated. It should be evaluated to prevent its adverse effects on the patients' quality of life. It is essential for adequate pain management to understand the pathophysiology of the condition in each individual suffering from ALS.<sup>4</sup>

### 2. Neurodegenerative mechanism of ALS

The most common adult onset primarily motor neuron disease is ALS. It was depicted by unalterable

progressive loss of motor neurons at the level of the motor cortex, bulbar and spinal cord, which leads to death. This process results in weakness, spasticity and muscles atrophy proceeding to paralysis.<sup>8-10</sup> The onset is insidious, and although it can occur in people in their 20s and 30s, most occur between age 40 and 70 y, (average age of diagnosis is 50 y); men are more affected than women.<sup>9</sup> The etiology of ALS is largely unknown.<sup>11</sup> The disease development is significantly influenced by interaction of genetic, lifestyle and environment, promote to critical environmental and epigenetic factors dysfunction.<sup>2,12</sup>

There are two types of ALS that cannot be discerned clinically, sporadic and familial-type. Sporadic ALS (sALS) is an ALS type without a family history (90–95% of all cases) while the familial type ALS (fALS), an ALS type with a history of familial genetic mutations, reflects 5–10% of all cases.<sup>8,13</sup> To explain ALS pathogenesis, understanding the relation between dysfunction of upper motor neurons (UMN and lower

The dying forward hypothesis states that ALS is preceded by hyperexcitability in corticomotoneuron which induces degeneration of the anterior horn cells. This process is mediated by the degeneration of anterograde motor neurons through the process of glutamate excitotoxicity.<sup>12,14,15</sup> Meanwhile, dying back hypothesis proposed that ALS begins due to disorder of neuromuscular junction (NMJ) or muscle cells, in which motor neurotrophic hormone deficiency was present and perilous factors transported retrogradely to the cell body from NMJ.<sup>15,16</sup> The independent degeneration hypothesis proposed degeneration of upper and lower motor neuron occurs independently.<sup>12,15</sup>

Molecular and genetic complex interaction pathway seems to be mediating ALS. Astrocytic excitatory amino acid transporter-2 (EAAT2) dysfunction mediates glutamate excitotoxicity by reducing glutamate uptake from the synaptic cleft. Translation abnormalities and intracellular neuronal aggregates

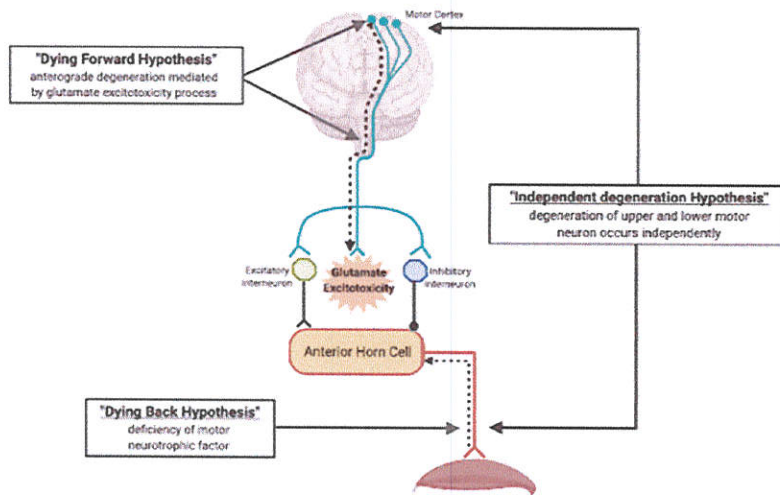


Figure 1: The illustration of three hypothesis for ALS

motor neurons (LMN), notably the onset site is crucial. There have been three hypotheses of how ALS occurs: dying forward, dying back and independent degeneration hypothesis.<sup>12</sup>

formation caused by TDP-43, c9orf72 and fused

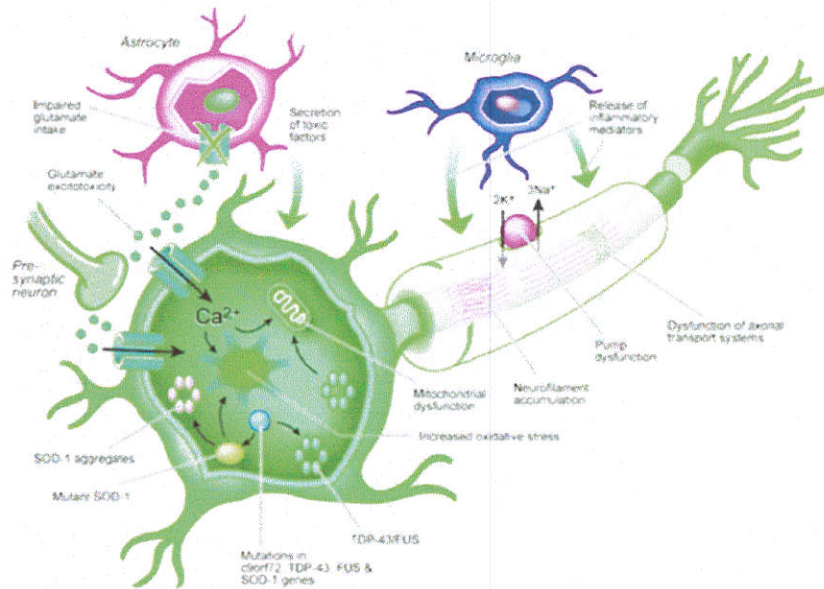


Figure 2: Molecular and genetic interaction in ALS pathogenesis

in sarcoma (FUS) genes mutations through dysregulation in RNA metabolism. Increased oxidative stress due to superoxide dismutases-1 (SOD-1) gene mutations, leading to intracellular aggregates and defective axonal transportation. Proinflammatory cytokines and neurotoxicity secretion are the result of microglia activation separately.<sup>12</sup>

ALS has a focal onset, unrelentingly progressive. Patient stricken with ALS can have several symptoms, mostly sorted as bulbar, spinal or respiratory, behavioural and/or cognitive alteration and pain.<sup>4,11,17,18</sup> The general bulbar symptoms such as facial weakness, words slurred, impaired tongue movements, sialorrhea, dysphagia are considered as consequence of UMN breakdown.<sup>17,18</sup> Respiratory symptoms can appear individually or simultaneously, patients frequently showing orthopnea, dyspnea, hypoventilation and weakness on respiratory muscle.<sup>17</sup> The main cause of weakness in ALS is LMN breakdown.<sup>11</sup> Fine motor disruption, arms and legs paralyzes, weakness and/or wasting and fasciculation

in the muscles of arm and leg are part of spinal onset symptoms.<sup>18</sup> It is now recognized that ALS implicates non-motor symptoms, such as cognitive and/or behavioural alteration and pain. The involvement of frontotemporal circuits occurs between 30%–50% patients who have cognitive alteration detected on a formal test.<sup>11</sup> Pain in ALS could manifest 2 years or more in advance of motor alteration. At the onset of disease, aching cramps in the hands or legs are often occurs.<sup>4</sup>

The recognition of coexisting UMN and LMN signs remain subservient to diagnose ALS, as well as sign of disease progressivity and neuromuscular mimicking disorder has excluded.<sup>16,19</sup> The great clinical variability presentation in the early stage of ALS has become burdensome to diagnose. The finding of UMN and LMN signs within distinct body regions described as bulbar, cervical, thoracic and lumbar was necessary to diagnose ALS.<sup>20</sup> Compelling diagnostic delays have been reported due to absence of a pathognomonic test and clinical phenotype variance. Numerous ALS staging have been suggested with uses such as a tool

for fast functional assessment, rehabilitation, distinct treatment models comparative, biomarker analysis and health economics.<sup>21</sup>

The World Federation of Neurology Research Group on Motor Neuron Diseases established clinical-based criteria called El Escorial criteria.<sup>16,20</sup> These criteria were first established in the year of 1991.<sup>22</sup> The exclusion of different etiologies of signs and symptoms is the base of ALS diagnosis, as described in the initial diagnostic criteria.<sup>23</sup> This criterion presents a set of guidelines to diagnose ALS, rest on disease spread pattern but are not in themselves a staging system.<sup>21</sup>

The diagnostic criteria of ALS confide in the finding of UMN and LMN signs within distinct regions described as bulbar, cervical, thoracic and lumbar regions.<sup>20</sup> Diagnosis of ALS was based on the revised El Escorial Criteria. It requires the existence of LMN degeneration signs (clinical, electrophysiological or neuropathologic examination), UMN degeneration signs (clinical examination), progressive expansion of signs within a region or to other region, following nonappearance of electrophysiological evidence of other disease processes that might explain the signs of LMN and/or UMN degenerations; and neuroimaging evidence of other disease processes that might explain the observed clinical and electrophysiological signs.<sup>24</sup>

The most extensively studied proposals have been the Milano-Torino (MiToS) functional staging and King's clinical staging systems.<sup>21</sup> The MiToS staging system relies on functional ability of four domains: movements, swallowing, communication and breathing, as appraised by the ALS Functional Rating Scale-Revised (ALSFRS-R), where stage 0 is a normal function and stage 5 is death.<sup>21,25</sup> The King's system is based on two domains: neurological regions (bulbar, cervical, thoracic, lumbar) and further prognostic criteria. It use five stages, with stage 1 being the symptom onset and 5 being the death.<sup>21,25</sup>

Afterwards, the neurophysiology-based Awaji criteria were established as an additional to the El Escorial criteria to intensify the ALS diagnosis sensitivity.<sup>16,26</sup> Based on the revised Awaji Criteria (2008), there is clinically definite, or probable or possible ALS. The clinically definite ALS is defined as clinical or electrophysiological evidence of UMN and LMN signs in bulbar region and at least two spinal regions,

or UMN and LMN signs in three spinal regions. The clinically probable ALS is defined as clinical or electrophysiological evidence of UMN and LMN signs in at least two regions, with some UMN sign rostral to LMN signs. The clinically possible ALS is defined as clinical or electrophysiological evidence of UMN and LMN signs alone in two or more regions, or LMN signs rostral to UMN signs.<sup>20</sup>

No cure in ALS has been found yet. The average ALS survival is around 2–5 y, but some patients with more passive disease progression are able to get through for over a decade. Individual clinical management in ALS patients can be optimized by multidisciplinary treatment. The fundamental management is symptomatic, supportive and neuroprotective treatment; likewise some vague disease-modifying treatment, e.g., gene therapy and stem cell transplantation have also been tried.<sup>20,27</sup> Two treatments have been identified as a disease-modifying therapy: riluzole and edavarone. Excitotoxicity has been thought to play a role in ALS pathophysiology. Riluzole targets excitotoxicity by act as an anti-glutamatergic agent. Although the definite mechanism of riluzole in ALS is not well established yet, it slows the disease progressivity. Edavarone is a strong antioxidant agent works by eliminating hydroxyl radicals and lipid peroxides. The mechanism of action in ALS is also unclear.<sup>27</sup> The use of riluzole has strong evidence according to American Association of Neurology (AAN) guideline for the care of the patient in ALS (Level A), it is also recommended by European Federation of the Neurological Societies (EFNS) to initiate the treatment as soon as possible with dose 50 mg q12h (Level A).<sup>28,29</sup> A variety of other drugs, including anti-apoptotic agent, anti-inflammatory, anti-excitotoxicity, anti-oxidant, anti-aggregation, neuroprotection and neurotrophic growth factor, glial-restricted precursor, cell-based therapy, neural gene therapy and progenitor stem cells are still being studied and under researched.<sup>27</sup>

### 3. Pathogenesis of pain in ALS

The current definition of pain as endorsed by the International Association for the Study of Pain (IASP) is "An unpleasant sensory and emotional experience

associated with actual or potential tissue damage, or described in terms of such damage<sup>30</sup>. Pain is a response to tissue injury, noxious stimuli, or trauma. Nociceptive pain transmissions to the brain are affected by duration, functional abnormality and /or structural change of nerve.<sup>7</sup> Nociceptive pain arises from actual or threatened damage to non-neural tissue and is due to the activation of nociceptors and neuropathic pain is caused by a lesion or disease of the somatosensory nervous system.<sup>30</sup>

ALS cause pain in many patients although it is not considered to be a primary consequence of ALS. Yet, there's a lack of research regarding the pathogenesis of pain in ALS and the effective means to achieve nociceptive control.<sup>7</sup> Pain incidence ranges from 15% to 85% in ALS patients.<sup>4</sup> It has been suggested the first disturbance of the sensory system in ALS generates a dorsal root ganglia neuropathy followed by progressive sensory axonal atrophy, secondary demyelination–remyelination and eventual axonal loss.<sup>31,32</sup>

Although, it has been said that neuropathic pain, as well as spontaneous (tingling, paroxysmal shooting, burning sensation) and provoked (hyperalgesia, aftersensation, allodynia) manifestation are the primary matters of pain in ALS, but some studies showed different results. As the disease progresses, secondary matters (mostly nociceptive) of ALS pain begin to emerge. Prolonged immobility, muscle weakness and atrophy leads to degenerative changes in bones, joints and connective tissue causing a musculoskeletal pain. In the terminal phase of the disease, several patients also have general and unexplained pain.<sup>4</sup>

A study of pain characteristics in ALS carried out by Hanisch et al., showed that 53% of patients with ALS informed pain in several sites. The most frequent sites are; the back (50%), the extremities (47%), and the joints (42%). It was proposed that the pain is caused by bone and joint stress due to muscular atrophy. The disease duration and pain severity was not related according to this study.<sup>3</sup>

A different study by Moisset et al., assessed a large population of ALS patients with neuropathic pain to determine the characteristics and the prevalence. It showed that 65.6% ALS patients reported pain, out of which 9% exhibited neuropathic characteristic. Pain

was frequently described as spontaneous (rarely evoked), numbness, electric shock like, burning, tingling and pins-and needle. In this study, there were no relations to patients age or gender, disease duration, onset of bulbar or spinal disease, respiratory or nutritional status.<sup>33</sup>

A spinal MRI studies using diffusion tensor imaging (DTI), magnetization transfer (MT) imaging and inhomogeneous magnetization transfer (ihMT) imaging showed progressive degeneration of sensory tract and dorsal column over time. Pathology of dorsal column was able to be detected soon after symptoms onset. It suggests sensory involvement is fairly an initial ALS feature.<sup>34</sup> Study combining spinal DTI and neurophysiology ascertained significant sensory pathway degeneration in ALS patient lacking sensory symptoms, it disclosed sub-clinical sensory deficits in 85% of ALS patients.<sup>34,35</sup>

#### 4. Pain management in ALS

Since pain is an adequately manageable condition, it is quite disturbing that inadequate pain management had significant impact on ALS patients' social well-being and emotional health. There are several factors, which contribute to inadequate pain management in ALS since it is not a principle consequence of the disease. Regular pain screening is infrequently done in patient with ALS.<sup>7</sup> The good clinical practice must be the basis to manage pain in ALS since there are still no particular pain management guideline for ALS. Treatment may follow the pattern of non-malignant chronic pain guideline, which are readily available.<sup>29,36</sup>

Pharmacological therapy for primary and secondary pain in ALS can be classified according to the drug's mechanism of action. It includes medications for neuropathic pain, cramps, spasticity, and analgesics for pain relief from immobilization.<sup>4</sup> Neuropathic pain medication is chosen based on the guideline for the management of neuropathic pain for any cause. Therapies chosen as the first line include gabapentin (900–3600 mg / day), pregabalin (150–600 mg / day) and tricyclic antidepressants (59–100 mg / day).<sup>4,37</sup>

Levetiracetam can be given as a first-line therapy at a dose of 1500–3000 mg / day to manage spasticity.<sup>38</sup> Intrathecal baclofen can be used as a second-line anti-spasticity drug.<sup>4</sup> A case series in 8 ALS patients used intrathecal baclofen at a dose of 25–50 µg / day, and

**Commented [11]:** Pemberian baklofen IT dilakukan jika spastisitas tidak teratasi dengan tx oral tunggal, oral kombinasi maupun physical tx → perlu dipertimbangkan penambahan evidence dan rekomendasi baclofen IT sbg second line

was able to reduce pain intensity by 54%.<sup>39</sup> Co-administration of levetiracetam and baclofen intrathecal should be avoided. Other drugs that can be given include baclofen oral twice or thrice a day in 10 mg dose, tizanidine 6–24 mg/day, dantrolene 25–100 mg/day, and benzodiazepines such as diazepam 10–30 mg/day.<sup>4,7,29,40</sup> Intramuscular botulinum toxin (BoNT) injections also utilized as a treatment to reduce ALS spasticity.<sup>7</sup> Spasticity might be safe and effectively prevented with routine stretching, passive or active range-of-motion exercise. Painful and function-limiting contractures, especially at the ankle and shoulder joints can be prevented with regular, proactive stretching plans. These methods are beneficial for maintaining physical mobility and muscle length as well.<sup>41</sup>

Stretching and massaging is clinically effective for treating cramps in the superior and inferior extremities, the abdomen. The first-line drug that can be given is quinine sulphate at a dose of 250–500 mg/day, which is known to reduce the number and intensity of cramps at any cause. Other therapies that can be given are gabapentin, mexiletine, dronabinol and levetiracetam.<sup>4,38,41,42</sup>

Nonsteroidal anti-inflammatory drugs (NSAIDs), paracetamol, and opioids are some analgesics that can be used to treat pain due to immobilization.<sup>4,7</sup> NSAIDs and paracetamol were chosen to be the first-line therapy.<sup>4</sup> To treat acute nociceptive and neuropathic pain, a combination of paracetamol and codeine can be used.<sup>4</sup> Opioids are a second-line therapy option for pain that is not treated with first-line therapy.<sup>4</sup> Daily assistive ROM exercises based on clinical experience can also help reduce pain due to mobilization.<sup>41</sup> Avoid strenuous exercise, choose exercises with a low risk of falling. This approach is also useful for maintaining muscle strength and physical mobility. Other therapeutic modalities include acupuncture, transcutaneous electrical nerve stimulation, cold and warm compresses, and intra-articular steroid injection with or without lidocaine.<sup>4,41</sup>

Medication treatment given in the early course of the disease aims to control muscle cramps and fasciculations. Vitamin E or magnesium are often utilized to treat mild muscle twitches.<sup>7</sup> Higher doses might cause fatigue, sedation and weakness, which may aggravate the progression of the disease.<sup>7</sup>

## 5. Conclusion

ALS sufferers can encounter pain due to spasticity, cramps and decreased mobility. A study of pain in ALS is less well documented, it is potentially overlooked and undertreated by physicians. It can arise along the course of the disease and requires treatment. A multidisciplinary management should be opted to treat pain related to ALS to achieve better quality of life in patients suffering from ALS.

## 6. Conflict of interest

None declared by the authors

## 7. Authors' contribution

All authors contributed in the concept and drafting and editing the manuscript

## 8. References

- Oskarsson B, Gendron TF, Staff NP. Amyotrophic lateral sclerosis: an update for 2018. *Mayo Clin Proc*. 2018;93(11):1617–28. [PubMed] DOI: [10.1016/j.mayocp.2018.04.007](https://doi.org/10.1016/j.mayocp.2018.04.007)
- Luna J, Diagana M, Ait Aissa L, Tazir M, Ali Pacha L, Kacem I, et al. Clinical features and prognosis of amyotrophic lateral sclerosis in Africa: The TROPALS study. *J Neurol Neurosurg Psychiatry*. 2019;90(1):20–9. [PubMed] DOI: [10.1136/nnp.2018.318469](https://doi.org/10.1136/nnp.2018.318469)
- Bandres-Ciga S, Noyce AJ, Hemani G, Nicolas A, Calvo A, Mora G, et al. Shared polygenic risk and causal inferences in amyotrophic lateral sclerosis. *Ann Neurol*. 2019;85(4):470–81. [PubMed] DOI: [10.1002/ana.25431](https://doi.org/10.1002/ana.25431)
- Chiò A, Mora G, Lauria G. Pain in amyotrophic lateral sclerosis. *Lancet Neurol*. 2017;16(2):144–57. [PubMed] DOI: [10.1016/S1474-4422\(16\)30358-1](https://doi.org/10.1016/S1474-4422(16)30358-1)
- Hanisch F, Skudlarek A, Berndt J, Kornhuber ME. Characteristics of pain in amyotrophic lateral sclerosis. *Brain Behav*. 2015;5(3):8. [PubMed] DOI: [10.1002/brb3.296](https://doi.org/10.1002/brb3.296)
- Lian L, Liu M, Cui L, Guan Y, Liu T, Cui B, et al. Environmental risk factors and amyotrophic lateral sclerosis (ALS): A case-control study of ALS in China. *J Clin Neurosci*. 2019;66:12–8. [PubMed] DOI: [10.1016/j.jocn.2019.05.036](https://doi.org/10.1016/j.jocn.2019.05.036)
- Handy CR, Krudy C, Boulis N, Federici T. Pain in amyotrophic lateral sclerosis: A Neglected aspect of disease. *Neurol Res Int*. 2011;2011:403808. [PubMed] DOI: [10.1155/2011/403808](https://doi.org/10.1155/2011/403808)

**Commented [12]:** Pertimbangkan untuk mencantumkan evidence terkait quinine sebagai 1st line tx untuk kram pada ALS, karena FDA sudah tidak merekomendasikan quinine sbg 1st line → terkait ESO dan efikasi quinine yg kurang adekuat.

8. Campanari ML, Bourefis AR, Kabashi E. Diagnostic challenge and neuromuscular junction contribution to ALS pathogenesis. *Front Neurol*. 2019 Feb 6;10:68. [PubMed] DOI: [10.3389/fneur.2019.00068](https://doi.org/10.3389/fneur.2019.00068)
9. Lawson V, Robbins NM. The potential misdiagnosis of multifocal motor neuropathy as amyotrophic lateral sclerosis—a case series. *Eur Neurol Rev*. 2018;14(2):102–7. [FreeFullText]
10. Dai Z, Chen Y, Yan G, Gang xiao, Shen Z, Wu R. Progress of magnetic resonance imaging in amyotrophic lateral sclerosis. *Radiol Infect Dis*. 2019;6(1):1–7. DOI: [10.1016/j.riid.2018.11.002](https://doi.org/10.1016/j.riid.2018.11.002)
11. Martin S, Al Khleifat A, Al-Chalabi A. What causes amyotrophic lateral sclerosis? *F1000Res*. 2017;6(0):1–10. [PubMed] DOI: [10.12688/f1000research.10476.1](https://doi.org/10.12688/f1000research.10476.1)
12. van den Bos MAJ, Geevasinga N, Higashihara M, Menon P, Vucic S. Pathophysiology and diagnosis of ALS: Insights from advances in neurophysiological techniques. *Int J Mol Sci*. 2019;20(11):2818. [PubMed] DOI: [10.3390/ijms20112818](https://doi.org/10.3390/ijms20112818)
13. Cappella M, Ciotti C, Cohen–Tannoudji M, Biferi MG. Gene therapy for ALS—A perspective. *Int J Mol Sci*. 2019;20(18):4388. [PubMed] DOI: [10.3390/ijms20184388](https://doi.org/10.3390/ijms20184388)
14. Vucic S, Ziemann U, Eisen A, Hallett M, Kiernan MC. Transcranial magnetic stimulation and amyotrophic lateral sclerosis: Pathophysiological insights. *J Neurol Neurosurg Psychiatry*. 2013;84(10):1161–70. [PubMed] DOI: [10.1136/nmp-2012-304019](https://doi.org/10.1136/nmp-2012-304019)
15. Kiernan MC, Vucic S, Cheah BC, Turner MR, Eisen A, Hardiman O, et al. Amyotrophic lateral sclerosis. *Lancet*. 2011;377(9769):942–55. [PubMed] DOI: [10.1016/S0140-6736\(10\)61156-7](https://doi.org/10.1016/S0140-6736(10)61156-7)
16. Geevasinga N, Howells J, Menon P, Van Den Bos M, Shibuya K, Matamala JM, et al. Amyotrophic lateral sclerosis diagnostic index: Toward a personalized diagnosis of ALS. *Neurology*. 2019;92(6):e536–47. [PubMed] DOI: [10.1212/WNL.0000000000006876](https://doi.org/10.1212/WNL.0000000000006876)
17. Yedavalli V, Patil A, Shah P. Amyotrophic Lateral sclerosis and its mimics/variants: a comprehensive review. *J Clin Imaging Sci*. 2018;8(1):1–9. [PubMed] DOI: [10.4103/jcis.JCIS\\_40\\_18](https://doi.org/10.4103/jcis.JCIS_40_18)
18. Galvin M, Gaffney R, Corr B, Mays I, Hardiman O. From first symptoms to diagnosis of amyotrophic lateral sclerosis: Perspectives of an Irish informal caregiver cohort – A thematic analysis. *BMJ Open*. 2017;7(3). [PubMed] DOI: [10.1136/bmjopen-2016-014985](https://doi.org/10.1136/bmjopen-2016-014985)
19. Geevasinga N, Menon P, Özdinler PH, Kiernan MC, Vucic S. Pathophysiological and diagnostic implications of cortical dysfunction in ALS. *Nat Rev Neurol*. 2016;12(11):651–61. [PubMed] DOI: [10.1038/nrneurol.2016.140](https://doi.org/10.1038/nrneurol.2016.140)
20. Tao QQ, Wu ZY. Amyotrophic lateral sclerosis: Precise diagnosis and individualized treatment. *Chin Med J (Engl)*. 2017;130(19):2269–72. [PubMed] DOI: [10.4103/0366-6999.215323](https://doi.org/10.4103/0366-6999.215323)
21. Fang T, Al Khleifat A, Stahl DR, Lazo La Torre C, Murphy C, Young C, et al. Comparison of the King's and MiToS staging systems for ALS. *Amyotroph Lateral Scler Front Degener*. 2017;18(3–4):227–32. [PubMed] DOI: [10.1080/21678421.2016.1265566](https://doi.org/10.1080/21678421.2016.1265566)
22. Traynor BJ, Codd MB, Corr B, Forde C, Frost E, Hardiman OM. Clinical features of amyotrophic lateral sclerosis according to the El Escorial and Airie House diagnostic criteria: A population-based study. *Arch Neurol*. 2000;57(8):1171–6. [PubMed] DOI: [10.1001/archneur.57.8.1171](https://doi.org/10.1001/archneur.57.8.1171)
23. Ludolph A, Drory V, Hardiman O, Nakano I, Ravits J, Robberecht W, et al. A revision of the El Escorial criteria – 2015. *Amyotroph Lateral Scler Front Degener*. 2015;16(5–6):291–2. [PubMed] DOI: [10.3109/21678421.2015.1049183](https://doi.org/10.3109/21678421.2015.1049183)
24. Brooks BR. El escorial World Federation of Neurology criteria for the diagnosis of amyotrophic lateral sclerosis. *J Neurol Sci*. 1994;124(SUPPL):96–107. [PubMed] DOI: [10.1016/0022-510x\(94\)90191-0](https://doi.org/10.1016/0022-510x(94)90191-0)
25. Corcia P, Beltran S, Laurette G, Bakkouche S, Couratier P. Staging amyotrophic lateral sclerosis: A new focus on progression. *Rev Neurol (Paris)*. 2019;175(5):277–82. [PubMed] DOI: [10.1016/j.neuro.2018.09.017](https://doi.org/10.1016/j.neuro.2018.09.017)
26. Li DW, Liu M, Cui B, Fang J, Guan YZ, Ding Q, et al. The Awaji criteria increases the diagnostic sensitivity of the revised El Escorial criteria for amyotrophic lateral sclerosis diagnosis in a Chinese population. *PLoS One*. 2017;12(3):1–8. [PubMed] DOI: [10.1371/journal.pone.0171522](https://doi.org/10.1371/journal.pone.0171522)
27. Nowicka N, Juranek J, Juranek JK, Wojtkiewicz J. Risk factors and emerging therapies in amyotrophic lateral sclerosis. *Int J Mol Sci*. 2019;20(11):2616. [PubMed] DOI: [10.3390/ijms20112616](https://doi.org/10.3390/ijms20112616)
28. AAN. The care of the patient with amyotrophic lateral sclerosis : drug , nutritional , and respiratory therapies. 2009. Available from: <https://www.aan.com/Guidelines/Home/GetGuidelineContent/373>
29. Andersen PM, Abrahams S, Borasio GD, de Carvalho M, Chio A, Van Damme P, et al. EFNS guidelines on the Clinical Management of Amyotrophic Lateral Sclerosis (MALS) – revised report of an EFNS task force. *Eur J Neurol*. 2012;19(3):360–75. [PubMed] DOI:

## pain in amyotrophic lateral sclerosis



- [10.1111/j.1468-1331.2011.03501.x](https://doi.org/10.1111/j.1468-1331.2011.03501.x)
30. Trouvin AP, Perrot S. New concepts of pain. *Best Pract Res Clin Rheumatol.* 2019;33(3):101415. [PubMed] DOI: [10.1016/j.berh.2019.04.007](https://doi.org/10.1016/j.berh.2019.04.007)
  31. Heads T, Pollock M, Robertson A, Sutherland WHF, Allpress S. Sensory nerve pathology in amyotrophic lateral sclerosis. *Acta Neuropathol.* 1991;82(4):316–20. [PubMed] DOI: [10.1007/BF00308818](https://doi.org/10.1007/BF00308818)
  32. Isaacs JD, Dean AF, Shaw CE, Al-Chalabi A, Mills KR, Leigh PN. Amyotrophic lateral sclerosis with sensory neuropathy: Part of a multisystem disorder? *J Neurol Neurosurg Psychiatry.* 2007;78(7):750–3. [PubMed] DOI: [10.1136/nnp.2006.098798](https://doi.org/10.1136/nnp.2006.098798)
  33. Moisset X, Cornut-Chauvinc C, Clavelou P, Pereira B, Dallel R, Guy N. Is there pain with neuropathic characteristics in patients with amyotrophic lateral sclerosis? A cross-sectional study. *Palliat Med.* 2016;30(5):486–94. [PubMed] DOI: [10.1177/0269216315600332](https://doi.org/10.1177/0269216315600332)
  34. El Mendili MM, Querin G, Bede P, Pradat PF. Spinal cord imaging in amyotrophic lateral sclerosis: Historical concepts—novel techniques. *Front Neurol.* 2019;10:1–11. [PubMed] DOI: [10.3389/fneur.2019.00350](https://doi.org/10.3389/fneur.2019.00350)
  35. Iglesias C, Sangari S, Mendili MM El, Benali H, Marchand-Pauvert V, Pradat PF. Electrophysiological and spinal imaging evidences for sensory dysfunction in amyotrophic lateral sclerosis. *BMJ Open.* 2015;5(2):1–10. [PubMed] DOI: [10.1136/bmjopen-2015-007659](https://doi.org/10.1136/bmjopen-2015-007659)
  36. Arthur KC, Calvo A, Price TR, Geiger JT, Chio A, Traynor BJ. Projected increase in amyotrophic lateral sclerosis from 2015 to 2040. *Nat Commun.* 2016;7:1–6. [PubMed] DOI: [10.1038/ncomms12408](https://doi.org/10.1038/ncomms12408)
  37. Attal N, Cruccu G, Baron R, Haanpää M, Hansson P, Jensen TS, et al. EFNS guidelines on the pharmacological treatment of neuropathic pain: 2010 revision. *Eur J Neurol.* 2010;17(9):1113–e88. [PubMed] DOI: [10.1111/j.1468-1331.2010.02999.x](https://doi.org/10.1111/j.1468-1331.2010.02999.x)
  38. Bedlack RS, Pastula DM, Hawes J, Heydt D. Open-label pilot trial of levetiracetam for cramps and spasticity in patients with motor neuron disease. *Amyotroph Lateral Scler.* 2009;10(4):210–5. [PubMed] DOI: [10.1080/17482960802430773](https://doi.org/10.1080/17482960802430773)
  39. McClelland S, Bethoux FA, Boulis NM, Sutliff MH, Stough DK, Schwetz KM, et al. Intrathecal baclofen for spasticity-related pain in amyotrophic lateral sclerosis: Efficacy and factors associated with pain relief. *Muscle Nerve.* 2008;37(3):396–8. [PubMed] DOI: [10.1002/mus.20900](https://doi.org/10.1002/mus.20900)
  40. Mitchell J, Borasio G. Amyotrophic lateral sclerosis. *Lancet.* 2007;369:2031–41. [PubMed] DOI: [10.1016/S0140-6736\(07\)60944-1](https://doi.org/10.1016/S0140-6736(07)60944-1)
  41. Majmudar S, Wu J, Paganoni S. Rehabilitation in amyotrophic lateral sclerosis: Why it matters. *Muscle Nerve.* 2014;50(1):4–13. [PubMed] DOI: [10.1002/mus.24202](https://doi.org/10.1002/mus.24202)
  42. Blatzheim K. Interdisciplinary palliative care, including massage, in treatment of amyotrophic lateral sclerosis. *J Bodyw Mov Ther.* 2009;13(4):328–35. [PubMed] DOI: [10.1016/j.jbmt.2008.04.040](https://doi.org/10.1016/j.jbmt.2008.04.040)

## pain in amyotrophic lateral sclerosis