

The Evolving Role of Anaesthesiologist in Chronic Pain Management: A Narrative Review on Innovations and Future Perspectives

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ABSTRACT

Chronic pain is a widespread and complex medical condition that profoundly diminishes the quality of life, emotional status and functional ability. As knowledge about pain pathophysiology becomes more profound, the anaesthesiologist's role has been extended beyond the perioperative period to become responsible for chronic pain management. This narrative review discusses the changing roles of anaesthesiologists in diagnosing, treating and managing chronic pain patients, offering an in-depth review of recent pharmacological approaches, interventional methods and advanced neuromodulation techniques applied in the practice setting. It highlights the relevance of multimodal and multidisciplinary pain management paradigms that incorporate physical, psychological and behavioural therapies. Together with tried-and-tested approaches, new advances like regenerative medicine, precision pain management and health technologies involving digital interventions—e.g., mobile applications and wearable monitoring—are presented. Increasing integration of Artificial Intelligence (AI) and machine learning with personalised pain care represents a new frontier, promising greater diagnostic accuracy, treatment planning and predictive outcomes. Despite these advances, persistent difficulties continue to exist, such as subjective pain measurement, opioid addiction, unequal access to treatment and systemic barriers to healthcare. The originality of this review lies in its holistic approach, crossing traditional methods with innovative technologies and patient-oriented models of care. It highlights the pivotal role of anaesthesiologists in changing the pain management paradigm for chronic conditions from mere symptom control to functional recovery and improved quality of life, while also mapping out future pathways in terms of innovation, education and policy reforms that can enable anaesthesiologists to spearhead this revolution in pain medicine.

Keywords: Anaesthesiology, Interventional techniques, Multimodal analgesia, Neuromodulation, Pharmacotherapy, Regenerative medicine

INTRODUCTION

Chronic pain remains one of the most prevalent and challenging health problems in contemporary medicine, affecting millions of individuals across all segments of society. About 30% of the world's population suffers from chronic pain and prevalence estimates differ by region. In Europe, a survey has given estimates between 12-30%, while in areas of Asia, prevalence is quite variable. Singapore, for example, has a lower prevalence rate of about 8.7%, while Japan has a higher rate of 17.5% and Thailand has a rate of 19.9%. Myanmar has a relatively low prevalence rate of 5.9%. These statistics bring into perspective the prevalence of chronic pain, although its prevalence differs greatly based on geographic and demographic considerations. Unlike acute pain, which is usually a consequence of direct tissue injury and vanishes when the process of healing has taken place, chronic pain persists longer than expected recovery periods and cannot always have a clear-cut pathological explanation. Chronic pain is widely recognised as an independent clinical condition that dramatically impairs quality of life, functional capacity and psychological wellbeing. Chronic pain management by its very nature, is complex, since it has a multifactorial aetiology and is both subjective and chronic. In the last several decades, anaesthesiologists have emerged as leaders in the general management of chronic pain, outside the confines of the operating room into the realm of long-term multidisciplinary pain management. With advanced education in pain physiology, pharmacotherapeutics and procedural interventions, anaesthesiologists are best suited to address the complex and subtle needs of chronic pain patients [1,2].

This review intends to investigate the widening horizon of anaesthesiology in chronic pain management by reviewing established and new techniques implemented in clinical practice. This review offers a complete overview of pharmacologic interventions, interventional treatments and sophisticated neuromodulation methods used by anaesthesiologists to treat chronic pain. Moreover, the review addresses the incorporation of multidisciplinary methods that integrate physical, psychological and behavioural therapies in line with the trend toward holistic and patient-centred care models.

OVERVIEW OF CHRONIC PAIN AND ITS IMPACT

Chronic pain is pain that lasts more than three to six months or more than the normal healing time of an injury. It may be nociceptive, neuropathic, or mixed, depending on the mechanisms. It may occur due to identifiable conditions such as osteoarthritis, diabetic neuropathy, or Complex Regional Pain Syndrome (CRPS), or may be idiopathic, such as fibromyalgia. The epidemiologic burden of chronic pain is staggering, with estimates suggesting that up to 20-30% of the global population suffers from some form of persistent pain. The financial cost is also substantial, both in the form of direct healthcare costs and indirect costs associated with lost productivity, long-term disability and dependence upon social support mechanisms [3].

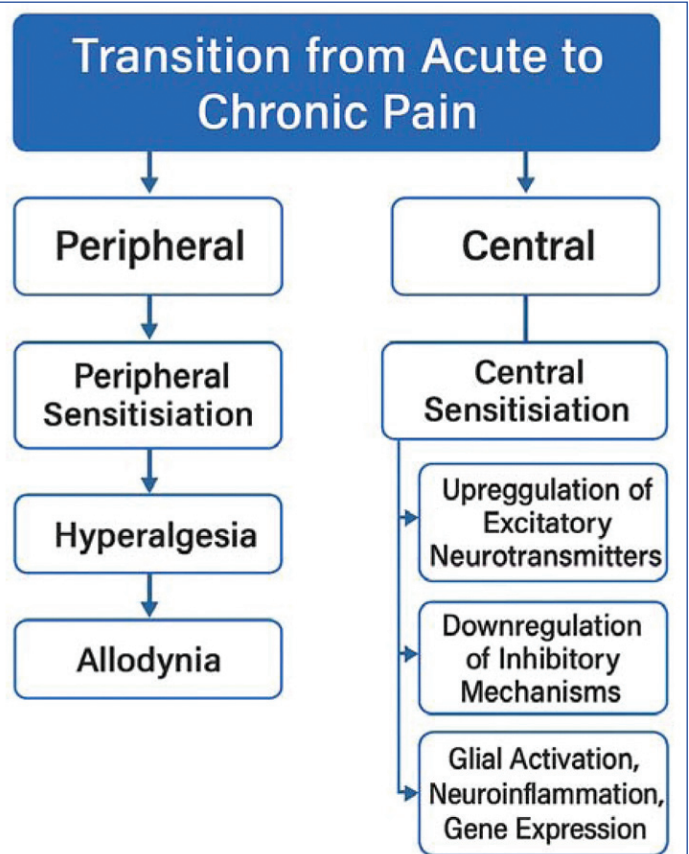
Chronic pain invariably leads to severe impairment of physical, emotional and social functioning. The patient generally complains of decreased mobility, decreased work or leisure activity participation, disturbed sleep and decreased interpersonal relationships. There

is a strong psychological effect with high rates of co-morbid depression, anxiety, substance abuse disorders and suicidal thoughts. Additionally, societal stigmatisation of concealed illnesses, as well as treatment for opioids, can reinforce isolation and hinder the empowerment of chronic pain patients. Chronic pain is more than a symptom of another disease but instead an illness in itself, deserving complete and continuous curative treatment, in which anaesthesiologists have principal roles [4].

Mechanisms of Chronic Pain

The transition from an acute to chronic pain is an advanced neurobiological process that alters the generation, conduction and perception of pain signals. At the peripheral level, persistent noxious stimuli can sensitise nociceptors—pain receptors on the skin, muscles and visceral organs. Peripheral sensitisation results in hyperalgesia, where even minimal stimuli elicit intense pain and allodynia, in which innocuous stimuli become painful. Central sensitisation is the process of nociceptive input magnification at the spinal cord and brain, large part due to the upregulation of excitatory neurotransmitters such as glutamate and downregulation of inhibitory mechanisms on Gamma-Aminobutyric Acid (GABA) and glycine. Glial cell activation, neuroinflammation and gene expression alterations also contribute to chronic pain states.

Functional imaging studies have demonstrated structural and functional changes in the key regions of the brain involved in pain modulation, such as the prefrontal cortex, thalamus, anterior cingulate cortex and insula, in chronic pain patients. Pain is no longer a strictly sensory event but a complex cognitive and affective experience influenced by attention, memory, mood and expectations. These results have revolutionised the concept of chronic pain from a solitary nociceptive disorder to a dynamic central nervous system disorder, highlighting the need for comprehensive treatment strategies that anaesthesiologists, because of their neurophysiological training, are uniquely qualified to offer [5,6]. [Table/Fig-1] illustrates the physiological changes that underpin the transition from acute to chronic pain, depicting both peripheral and central sensitisation pathways.



[Table/Fig-1]: The physiological changes that underpin the transition from acute to chronic pain.

Anaesthesiologist’s Role in Chronic Pain Care

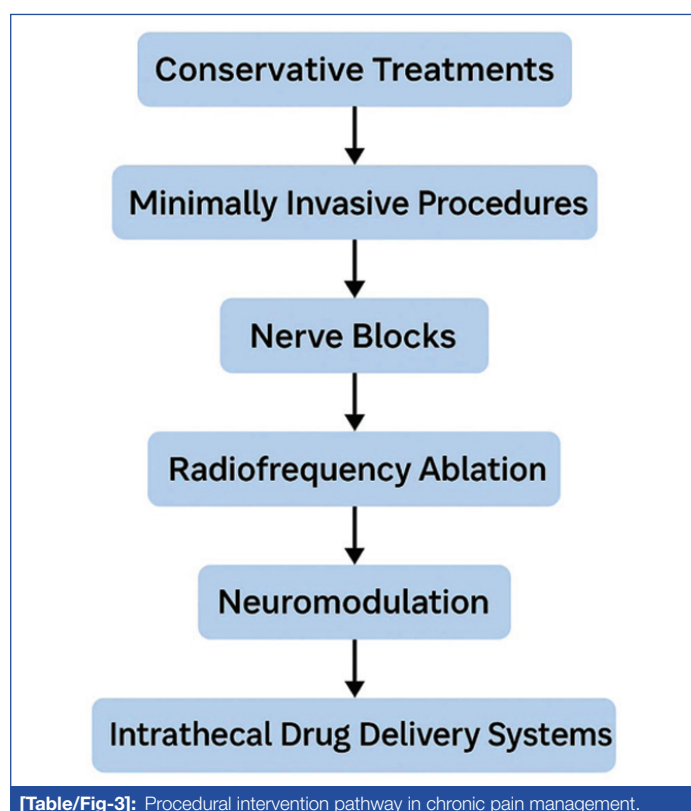
Historically associated with perioperative care and regulation of acute pain, anaesthesiologists have extended their scope of practice to incorporate extended treatment of chronic pain. The field of pain medicine, at times a fellowship following training in anaesthesiology, is now recognised as an accepted subspecialty by medical boards worldwide. Anaesthesiologists in this specialty are proficient not only in the performance of regional and neuraxial blocks, but they are also qualified to diagnose complex pain syndromes, manage pharmacologic regimens and carry out more sophisticated interventional procedures. The anaesthesiologist’s approach begins with a thorough evaluation of the patient’s pain history, physical examination, psychological assessment and imaging and diagnostic information. Attention is given to the identification of the pain generator—whether musculoskeletal, neuropathic, or visceral—and to psychological and social factors affecting the patient’s pain. Treatment approaches are significantly individualised and consist of pharmacologic, interventional, rehabilitative and behavioural treatments [7]. To further clarify the anaesthesiologist’s comprehensive role in chronic pain management, [Table/Fig-2] illustrates the clinical workflow highlighting key stages of involvement.



[Table/Fig-2]: Clinical workflow of an anaesthesiologist in chronic pain management.

In procedural pain management, anaesthesiologists play a leading role in performing image-guided procedures such as epidural steroid injections, facet joint blocks, sympathetic nerve blocks and radiofrequency ablations. They are prone to providing both diagnostic and therapeutic benefits and serve as gatekeepers to more advanced modalities such as neuromodulation and Intrathecal Drug Delivery Systems (IDDS). Furthermore, anaesthesiologists take an active role in multidisciplinary pain clinics alongside neurologists, psychiatrists, physiatrists and psychologists, with the potential to have an organised and comprehensive care model. The work of anaesthesiologists has evolved now to be

that of a complete pain physician, combining technical expertise with compassionate, longitudinal patient care [8]. To guide clinical decision-making, [Table/Fig-3] presents a stepwise procedural intervention pathway outlining the escalating interventional options under anaesthesiologist-led care.



CURRENT PHARMACOLOGICAL APPROACHES

Pharmacotherapy remains an active part of chronic pain therapy, but a multifaceted one that is often bounded by side-effects, tolerance and variability in efficacy. Non opioids such as Non Steroidal Anti-Inflammatory Drugs (NSAIDs), acetaminophen and topical analgesics are common place in the starting or milder stages of chronic pain, particularly for inflammatory and nociceptive components of chronic pain. Such drugs, being generally well tolerated, are at times insufficient when used to deal with neuropathic or central states of pain [9]. Adjuvant analgesics such as anticonvulsants (gabapentin, pregabalin) and antidepressants (duloxetine, amitriptyline) are an integral part of the management of neuropathic pain because of their action on abnormal neuronal firing and enhancement of descending inhibitory control. It is not unusual for anaesthesiologists to be involved in starting and titrating these medications, monitoring both effects and side-effects and educating patients about the time to onset of action and potential benefit [10].

The use of opioids for chronic non cancer pain remains controversial. While they may benefit some individuals, particularly those with unremitting nociceptive pain who are refractory to other types of treatment, the risk of tolerance, dependence, addiction and overdose are significant. The opioid epidemic has led to a shift towards evidence-based and rational prescribing, with comprehensive opioid risk assessments, the use of prescription drug monitoring programmes and the establishment of patient contracts becoming standard practice. Anaesthesiologists are leaders in promoting opioid stewardship and advocating for interventional and non opioid alternatives [11].

New pharmacologic agents such as cannabinoids, NMDA receptor antagonists (e.g., ketamine) and sodium channel blockers (e.g., lidocaine, mexiletine) offer further alternatives in certain situations. However, their safety and long-term effectiveness must

be clarified. As the number of pharmacologic therapies grows, the anaesthesiologists' contribution is invaluable in optimising therapy, minimising side-effects and coordinating drugs with global multimodal plans [10,12].

Interventional Techniques in Chronic Pain Management

Interventional pain management is a general category of minimally invasive interventions targeting specific anatomical structures responsible for chronic pain syndromes. These techniques are particularly useful when satisfactory relief by means of pharmacotherapy is lacking or occurs with intolerable side-effects. Because of their image-guided expertise and extensive knowledge of neuroanatomy, anaesthesiologists become a crucial component of delivering such interventions with precision and safety [13].

Epidural steroid injections, for example, are commonly utilised in the management of radicular pain due to disc herniation or spinal stenosis. Through direct delivery of corticosteroids into the epidural space, such injections aim to minimise inflammation and break the vicious cycle of nerve root irritation. Facet joint injection and medial branch block, on the other hand, are used both diagnostically and therapeutically to treat axial pain of the spine secondary to degenerative changes in the vertebral column. Refractory facet-mediated pain can be managed over a longer duration with radiofrequency ablation of medial branches, by denervating nerves of pain conduction [14].

Sympathetic blocks, such as stellate ganglion and lumbar sympathetic blocks, are valuable tools in the treatment of sympathetically mediated pain syndromes such as CRPS. Trigger point injections, sacroiliac joint injections and intrathecal pumps are a few others within the interventional group. In cancer patients with intractable visceral pain, neurolytic interventions such as celiac plexus or superior hypogastric plexus blocks can produce severe analgesia by chemically destroying pain pathways. Such interventions are typically carried out under ultrasound or fluoroscopic guidance to give accuracy and reduce complications. The anaesthesiologists also give substantial input in the selection of appropriate patients for interventional therapy, counselling them on probable outcomes and coordinating intervention with physical rehabilitation and psychotherapy to maximise long-term benefit [15].

Neuromodulation and Advanced Therapies

Neuromodulation is one of the most advanced treatments for chronic pain, involves the modification of nerve activity by electrical or chemical means. Spinal Cord Stimulation (SCS) is a pillar of neuromodulation, especially in the treatment of failed back surgery syndrome, postlaminectomy pain and peripheral neuropathies. In SCS, electrodes are implanted in the epidural space, providing electrical impulses that mask or modulate pain signals en route to the brain. The technology has evolved a great deal, with newer paradigms of high-frequency stimulation, burst stimulation and closed-loop systems offering more results with less paraesthesia [16].

Peripheral Nerve Stimulation (PNS) and Dorsal Root Ganglion (DRG) stimulation are other targeted neuromodulatory strategies. DRG stimulation, in reality has been revealed to be very effective in focal neuropathic pain, such as CRPS, since it can address segmental pain generators very specifically. IDDS, where pain medications like morphine or ziconotide are administered directly into the cerebrospinal fluid via implantable pumps, offer potent analgesia with fewer systemic side-effects. These newer treatments require meticulous patient selection, trial stimulation procedures and long-term follow-up—functions that anaesthesiologists in pain medicine are uniquely qualified to provide. The field of neuromodulation continues to evolve with the incorporation

of real-time feedback devices, wearable devices and minimally invasive percutaneous techniques. Anaesthesiologists are not only consumers but also engines for the research and development of new technologies [17].

Multimodal Pain Management Strategies

Due to the complicated and multigenetic aetiology of chronic pain, no single modality is sufficient in itself. Multimodal pain care requires the concurrent utilisation of pharmacologic, interventional, physical and psychological measures to manage the heterogeneous aspects of pain. A combined method based on the existence of numerous pieces of evidence depicting greater outcomes with regard to reduction, functional gains and patient satisfaction has been utilised [18].

Education about pain and self-management training are key aspects of multimodal care, enabling patients to engage actively in their recovery and form long-term coping skills. Anaesthesiologists are frequently called upon to occupy a central role as members of interprofessional pain care teams, bringing procedural skills and systemic practice to the implementation of well-coordinated, patient-focused care plans. Biopsychosocial practice is consistent with modern views of chronic pain as a multi-compartmental illness encompassing biological, psychological and social elements and is crucial to the attainment of genuinely sustainable, tangible improvement in patients' results [19].

EMERGING TRENDS AND INNOVATIONS

The science of chronic pain management is progressing at a frenetic pace, fuelled by technological innovations, neuroscientific breakthroughs and personalised medicine. Among the most exciting areas of research is the application of AI and machine learning for evaluating and designing pain treatment. They can mine big data sets to characterise pain phenotypes, predict outcomes to therapy and direct personalised treatment. Regenerative medicine also looms on the horizon, with modalities such as Platelet-Rich Plasma (PRP), stem cell therapy and prolotherapy becoming more prominent in the management of musculoskeletal and degenerative pain syndromes. These modalities are not necessarily pain-blocking but instead tissue repairing and restoring function [20,21].

Functional brain imaging and brain stimulation techniques, such as Transcranial Magnetic Stimulation (TMS) and transcranial Direct Current Stimulation (tDCS), provide non-invasive methods of modulating the cortical pain network in centralised pain syndrome. All of this coincides with innovative developments in wearables and health apps, spearheaded by smart smartphones that increase the monitoring of pain, adherence to therapy and the remote care capability to allow for more responsive long-term treatment [22].

Telemedicine has become a key master key in unlocking access to pain management care, especially in rural and underserved areas. Increasingly, anaesthesiologists are simplifying their practices to add these digital health solutions, offering virtual consultations, remote monitoring of opioid use and educating patients through digital education platforms.

As genomics and pharmacogenomics science move forward, the promise of precision pain medicine, with treatments personalised to the individual's genetic makeup, pain phenotype and neurobiological signature, is ever more in our sight. Anaesthesiologists, as heavy players in academic and translation science, stand at the forefront of closing the bench-to-bedside gap for these innovations [23].

Challenges in Chronic Pain Management

Even after dramatic advances in diagnostics, therapeutics and interventional strategies, chronic pain treatment continues to have a number of challenges—clinical, ethical, societal and systems-based. One of the most rudimentary of these is that pain is still

subjective. It lacks any single objective biomarker or test that can be used universally to estimate chronic pain, so quantification and follow-up become highly reliant on self-reports from the patients. This subjective framework necessarily makes diagnosis problematic in some situations, particularly for individuals with psychiatric comorbid illness or questionable aetiology [24].

The stigma of chronic pain therapy with opioids and the stigma of long-term opioid therapy runs extremely deep. Patients are often viewed with suspicion, labelled as drug seekers, or dismissed flatly as malingerers. This not only does this break down the physician-patient relationship but it also blocks and derails appropriate care. Anaesthesiologists, having to walk a tightrope between suspicion and sympathy, have the responsibility of educating others and speaking up for an unprejudiced, evidence-based practice of pain. From a therapeutic perspective, prolonged opioid treatment also presents chronic clinical and ethical challenges. Relief from pain must be weighed against dependence, overdose and diversion. Physician burnout and pushback against treating chronic pain have also been stimulated by regulation, monitoring of prescribers and increased documentation. Specialist pain services are also still disproportionately placed, particularly in rural and under-resourced communities where trained pain physicians and interventional facilities are thin on the ground [1,25].

Future Directions in Anaesthesia and Pain Medicine

In the coming years, the anaesthesiologist's contribution to chronic pain treatment will continue to expand with the progress of innovation, interdisciplinary cooperation and an evolving understanding of pain pathophysiology. The future direction of pain medicine lies not merely in symptom palliation but in the actual restoration of function and quality of life by precision, personalisation and prevention. One of the most promising areas is precision pain medicine, in which treatment is individualised based on genetic, neurobiological and psychosocial signatures. Newer neuroimaging, neurophysiology and pharmacogenomics will enable physicians to diagnose unique pain mechanisms in individual patients and individualise therapy to them—whether receptor-directed drug, neural stimulation device, or behavioural therapy. Anaesthesiologists, through their bicultural heritage of both pharmacology and neurobiology, are optimally suited to spearhead this revolution [26].

Advances in regenerative approaches, such as stem cell therapy and biological scaffolding, will continue to narrow the therapeutic gap between tissue repair and analgesia, particularly in degenerative musculoskeletal diseases. Likewise, non-invasive neuromodulation devices, such as transcutaneous vagus nerve stimulation and closed-loop brain-computer interfaces, are emerging as novel treatments for refractory central pain conditions, such as fibromyalgia and phantom limb pain. AI and machine learning have the potential to transform clinical workflows by improving diagnostic accuracy, forecasting treatment success and creating real-time analytics for optimal care. Virtual reality and immersive technologies are already under investigation for their effectiveness in pain distraction and neuroplasticity training. Telemedicine and digital therapeutics will be ubiquitous aspects of care delivery, optimising accessibility and continuity, especially in geographically dispersed groups [24,27].

Education reform will guarantee that each anaesthesiologist, with or without pain medicine specialisation, learns key competencies regarding chronic pain management. Communication competence, shared decision-making and psychosocial awareness will make patient interactions more humane and cost-effective. Ultimately, the era of pain control will be one of integration—of technology, biology, psychology and care, but not of modalities. Anaesthesiologists will play a dominant role as proceduralists, diagnosticians and patient advocates [28].

With these stimulating advances, there are some pragmatic hindrances to be noted. Translation of cutting-edge technologies,

like AI, neuroimaging and regenerative medicine into standard clinical use is fraught with challenges. Costs, the lack of reimbursement schemes and the requirement for the extensive building of infrastructure may prevent widespread uptake, especially in resource-poor environments. Barriers of regulations and the slow approval process for new AI applications and digital treatments may sacrifice clinical effectiveness. In addition, widespread adoption would need extensive training and reskilling of anaesthesiologists and other clinicians, which may put undue pressure on current education systems. Ethical issues, privacy of data and fairness in access to innovative therapies also need to be carefully thought through. Identifying and overcoming these limitations is crucial to making the future of chronic pain management is both innovative and inclusive [26-28].

CONCLUSION(S)

Chronic pain is perhaps the most frustrating and resistant public health issue of the modern era. Its broad physical, psychological and socio-economic effect warrants an integrated, formal and empathetic approach. Anaesthesiologists, whose role has traditionally been confined to the operating theatre, are now integral members of multidisciplinary chronic pain management teams. With a deep understanding of pain physiology, expertise with interventional techniques and growing responsibility for coordinated care, they are uniquely positioned to lead the evolution of pain medicine into a science capable not only of mitigating suffering but also of restoring hope and dignity. Chronic pain management practices using anaesthesia in today's era already reach as far as pharmacologic optimisation, image-guided procedures and neuromodulation. With multimodal and personalisation-based practices becoming a reality and the pace of technological advancements accelerating, the future bodies well to enhance outcomes, enhance access and enhance the quality of life for people with chronic pain. Through the adoption of innovation and promoting collaboration and patient-centred care, anaesthesiologists will continue to pave the way for the future of pain medicine, propelling it beyond the relief of symptoms to meaningful, holistic healing.

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