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Strategy for effective analgesia with intravenous buprenorphine in patients with acute postoperative pain

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Abstract

Background Analgesic treatment is the primary method for managing acute postoperative pain. Opioid analgesics are the main class of drugs used to treat moderate to severe pain, whether it is acute or chronic. These opioids differ in various ways, including their pharmacochemical properties, distribution and absorption rates, metabolism, and elimination pathways for the drug and its metabolites. These differences result in varying degrees of analgesic efficacy, which, in clinical practice, allows for the selection of the most effective drug that maximizes pain relief while ensuring safety. Buprenorphine is a semi-synthetic opioid with properties that are not yet fully understood. It has a wide range of applications in treating both acute and chronic pain, including non-cancer and cancer-related pain. One of the most significant clinical advantages of buprenorphine is its safety profile, which includes a ceiling effect on respiratory depression, no immunosuppressive effects, inhibition of hyperalgesia, no cumulative effects in patients with renal failure, and a low risk of constipation following its use.

Aim This study aims to analyze current reports on the use of intravenous buprenorphine as a first-line opioid analgesic for postoperative pain relief. The paper discusses the pharmacochemical properties of the drug and the mechanisms behind postoperative pain. Additionally, it presents the experiences of the pain management team at Copernicus Hospital in Gdansk regarding administering intravenous buprenorphine.

Material and methods The current literature on buprenorphine for treating moderate to severe acute pain has been reviewed, focusing on its effectiveness in managing postoperative pain following surgical procedures. Additionally, the experience of the Copernicus Hospital pain team with buprenorphine is summarized in a brief discussion.

Conclusion After reviewing current literature and recommendations, along with the experiences of the pain management team at Copernicus Hospital in Gdańsk, it can be concluded that buprenorphine is an analgesic that demonstrates a high level of efficacy and safety. When used in combination with non-opioid analgesics, buprenorphine achieves a synergistic effect, resulting in effective pain relief. This approach facilitates early patient rehabilitation and enables a swift return to normal activities, even following extensive surgical procedures.

Keywords Buprenorphine, Acute postoperative pain, Opioid analgesia, Intravenous buprenorphine, Pain

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Introduction

Acute postoperative pain is a common occurrence in daily clinical practice. Its intensity, incidence, and duration can vary widely, depending on factors such as the type of surgical procedure, the experience of medical personnel in managing postoperative pain, and the analgesics used. This type of pain has a nociceptive, somatic component and results from tissue damage caused during surgery [1]. Additionally, surgical trauma and pain can lead to endocrine disruptions, resulting in increased secretion of cortisol, catecholamines, and other stress hormones [2, 3].

Despite the significant advancements in regional anesthesiology techniques, the availability of effective analgesics, including opioid medications, and numerous studies aimed at reducing pain, postoperative pain still occurs in 14% to 70% of cases in both developed and developing countries [1, 4–6].

Buprenorphine is a semisynthetic opioid that acts as a partial agonist with a high affinity for mu (μ) opioid receptors. It also serves as an agonist with a low affinity for nociceptin receptors and functions as an antagonist with a high affinity for kappa (κ) and delta (δ) opioid receptors [7]. The substance was first synthesized in the 60 s years, and renewed interest has emerged due to its high safety profile, effectiveness in addiction therapy, ability to mitigate respiratory depression, absence of immunosuppressive effects, and unique anti-hyperalgesic properties [8].

Aim of study

This study aimed to evaluate the effectiveness of intravenous buprenorphine as a first-line opioid for analgesic treatment in patients following surgical procedures. The presentation included an overview of the drug's pharmacochemical properties, an explanation of the mechanism behind postoperative pain, and a discussion of the safety aspects of its use in the surgical ward. Additionally, current reports related to the drug were reviewed. The experience of the pain management team at Copernicus Hospital in Gdańsk was also highlighted, showcasing the use of buprenorphine as the primary analgesic for acute pain relief after surgery.

Material and methods

This article was written after reviewing various publications on the use of buprenorphine for treating acute moderate to severe postoperative pain. Sources such as PubMed, Google Scholar, and Mendeley were utilized, using key terms like "buprenorphine," "intravenous buprenorphine," and "acute postoperative pain" to find relevant studies. Out of 110 articles analyzed, those specifically related to buprenorphine's use in acute postoperative pain were selected for inclusion. Duplicate discussions on this topic were excluded from consideration. The article referenced a total of 90 publications and scientific reports. It detailed the mechanism of postoperative pain and presented the pharmacochemical properties of buprenorphine. Additionally, the pain management team's experience at Copernicus Hospital in Gdańsk was discussed, highlighting the use of buprenorphine as a first-line treatment for acute postoperative pain.

Mechanism of postoperative pain development

Acute postoperative pain is a type of nociceptive inflammatory pain that arises from tissue damage caused by surgery [9]. When nociceptive receptors are traumatized during the surgical procedure, a phenomenon known as hyperalgesia occurs. Hyperalgesia can be categorized into two types: primary hyperalgesia, which results from the sensitization of peripheral pain receptors, and secondary hyperalgesia, which is associated with the sensitization of the spinal cord and central nervous system structures [1, 10–12].

Damage to nociceptive receptors triggers the release of inflammatory mediators at the injury site. These mediators include prostaglandins, leukotrienes, serotonin, and bradykinins. They stimulate the release of peptides related to the gene for calcitonin and substance P. In the following stage, substances such as histamine, nerve growth factor, and norepinephrine cause blood vessels to dilate. This process results in what is commonly called an "inflammatory soup" [13, 14].

Impulses from peripheral nociceptive receptors are transmitted through delta (δ) fibers and.

C-type fibers to laminae II and V of the Rexed classification in the spinal cord. C-fibers also form synapses in lamina I of the Rexed system, where they act as second-order neurons [1].

In the spinal cord, there are two types of second-order neurons. The first type, located in the I Rexed lamina, responds to impulses from C-type fibers. The second type, found in the V Rexed lamina, is activated by noxious stimuli (incisions) and innocuous stimuli (pressure). Neurotransmitters in the V lamina, such as glutamate and aspartate, facilitate rapid synaptic transmission. This occurs by activating kainate ionotropic receptors (KARs), which regulate sodium and potassium currents, and amino-3-hydroxy-5-methyl-4-isoxazolopropionic acid (AMPA) receptors. Both AMPA and KAR receptors are mainly impermeable to calcium ions. Their activation is then followed by the stimulation of NMDA receptors [15].

N-methyl-D-aspartate (NMDA) receptors are found postsynaptically in the posterior horn of the spinal cord. They mediate responses resulting from polysynaptic discharges of primary nociceptive afferent fibers.

The activation of NMDA receptors is linked to impulse transmission in nociceptive afferent fibers, specifically those of Aδ and C types. Additionally, NMDA receptors play a crucial role in learning, memory, neuronal development, and plasticity, as well as in central sensitization associated with damage or inflammation in peripheral tissues [15, 16].

In the modulation of acute postoperative pain, both endogenous and exogenous opioids play a crucial role. They act on the presynaptic endings of primary afferent nociceptors through mu (μ) opioid receptors. This action indirectly blocks calcium channels and opens potassium channels. As a result, inhibiting calcium entry into the presynaptic nerve endings and increased potassium release lead to hyperpolarization. This process inhibits the release of pain neurotransmitters and induces analgesia. Additionally, the activation of descending nerve pathways in the cortex stimulates the release of neurotransmitters such as β-endorphins, enkephalins, and dynorphins, which are essential for pain modulation within the central nervous system [1].

The activation of descending pathways around the periaqueductal gray matter and midbrain occurs through the action of endorphins via the opioid receptor pathway. This activation leads to the projection of neurons to the medulla oblongata and locus coeruleus, where serotonin and norepinephrine are subsequently produced. In a further stage, descending fibers extend to the dorsolateral region of the spinal cord's posterior horn, forming synapses with primary afferent neurons [17, 18]. Descending pain-modulating neurons play a crucial role in the release of neurotransmitters in the spinal cord. They activate interneurons, which then release opioids in the posterior horn of the spinal cord. Neurotransmitters such as serotonin and norepinephrine help inhibit the release of pain mediators in nociceptive afferent signals, reducing the transmission of pain stimuli at the cellular level. When opioid analgesics are administered, they activate opioid receptors in the midbrain, leading to a decrease in pain signal transmission. The activation of opioid receptors at C-fiber endings in the spinal cord prevents the release of pain neurotransmitters. In contrast, the activation of peripheral opioid receptors inhibits nociceptor activation and the release of inflammatory mediators [1, 17, 18].

Table 1 illustrates and discusses the effects of acute postoperative pain on various organs and systems in a person.

Pharmacochemical properties and mechanisms of action of buprenorphine

Pharmacodynamics

Buprenorphine is a semisynthetic opioid drug derived from thebaine. It acts as a partial agonist at the mu (μ) and nociceptin receptors while functioning as an antagonist at the delta (δ) and kappa (κ) receptors [20, 21]. After a single dose of buprenorphine, several physiological effects occur due to activating the mu (μ) receptors, including slowed gastrointestinal peristalsis, constricted pupils, bradypnea (slow breathing), nausea and vomiting, and urinary retention. With repeated administration of the drug, additional effects such as bradycardia (slow heart rate) and hypotension (low blood pressure) may also occur. Similar to other opioid medications, tolerance to some of the effects of buprenorphine can develop over time [21, 22].

Buprenorphine acts as a partial agonist at mu (μ) receptors and is known for its ceiling effect regarding respiratory depression. This means that the dose–effect curve is not linear; instead, it has a sigmoidal shape that reaches a plateau below 100% efficacy. However, no ceiling effect has been observed for the analgesic properties of buprenorphine, even at high doses. Up to 10 mg/kg of body weight (bw), buprenorphine demonstrates a linear dose/effect relationship, indicating that increasing the dose leads to a corresponding increase in analgesic effect. In contrast, doses exceeding 10 mg/kg bw are linked to a decreased analgesic effect [22]. A dose of 10 mg/kg significantly exceeds the doses used in clinical practice, making buprenorphine a pure agonist in terms of its analgesic effect [21]. The ceiling effect of buprenorphine, regarding its depressant impact on the respiratory center in the central nervous system, is linked to a low risk of respiratory distress following its use. The differing characteristics of the dose–effect curve for the various effects of buprenorphine are likely due to its affinity for different mu receptor subtypes (μ). Consequently, while the ceiling effect does not apply to analgesia, it is present in relation to respiratory depression [21–24]. This is crucial in clinical practice, especially in surgical wards, and pertains to the safe administration of buprenorphine for postoperative pain relief.

Buprenorphine can be used as a first-line treatment for acute postoperative pain, especially in combination with other μ-opioid receptor agonists. This approach is effective because buprenorphine does not fully occupy all μ-opioid receptors, leaving a pool of free, unoccupied receptors available for additional medications.

In experimental studies, both the analgesic effects and side effects of the drug were completely reversible with naloxone administration. When the drug is used in high doses, higher doses of naloxone are required. Additionally, the slow dissociation of the drug from mu (μ) receptors is linked to a longer duration of naloxone administration needed to address symptoms of buprenorphine overdose [21].

Buprenorphine's antagonistic effect on kappa-type receptors (κ) is linked to its antihyperalgesic properties.

Table 1 Effects of acute postoperative pain on human organs and systems [1, 19]

Body system	The effect of untreated or inadequately treated pain within the system in question
Cardiovascular	* acceleration of heart rate and increase in blood pressure * increase in contractility of the heart muscle * increase in oxygen demand * increase in water retention, potential risk of fluid overload * increase in risk of myocardial ischemia and hemodynamic instability * increase in risk of venous thrombosis (due to immobilization by pain)
Respiratory	* reduction in airway airflow volume * tachypnoe * reduction in vital capacity * reduction in functional reserve volume, which clinically translates into the occurrence of atherectasia and accumulation of bronchial secretions * increased risk of developing infection, hypoxia and respiratory failure
Immunological	* increased susceptibility to infections * increased or decreased sensitivity to pain * activation of the HPA axis
Encocrine-metbolic	* increase in blood glucose levels * increase in cortisol production
Digestive	* decreased gastric emptying * slowed intestinal motility * nausea and vomiting * constipation * increased risk of developing gastrointestinal obstructio
Urinary	* urinary urgency * urinary incontinence
Muscular	* increase in muscle tension at the site of injury * muscle tremors * shivering * piloerection (goosebumps)
Nervous	* changes in pain modulation * risk of developing chronic pain * anxiety/fear * depression * concentration and attention deficit disorder * inhibition or promotion of pain stimulus

HPA hypothalamic-pituitary-adrenocortical axis

This effect arises from the drug's ability to block the pronociceptive action of dynorphin on these kappa receptors (κ). [25]. Additionally, substances that antagonize kappa receptors (κ) have demonstrated antidepressant effects. Clinical trials have confirmed the efficacy of buprenorphine in providing anti-anxiety and antidepressant effects, particularly in patients with depression that is resistant to other treatment options, including those in the geriatric population [26–28].

An important pharmacodynamic property of buprenorphine is its analgesic effect at the spinal cord level, which occurs through opioid receptors. Its mechanism of action at the supraspinal level differs from that of morphine or fentanyl and is not solely opioid-related. This distinction is evident from the lack of antagonistic effects when naloxone is administered into the brain's ventricles [29].

Buprenorphine can be administered in various ways for analgesic management, including parenterally, sublingually, rectally, and transdermally. It is 75–115 times more potent than morphine and has significant lipophilicity [30]. In acute postoperative pain with moderate to severe intensity, a dose of 0.3–0.6 mg can be used for effective pain relief, lasting 6–8 h [31].

Pharmacokinetics

Buprenorphine binds to plasma proteins at a rate of 96%. It crosses the blood–brain barrier and achieves a concentration that is 15–25% of that found in plasma. The drug is extensively distributed throughout the body, penetrating into bone and adipose tissue [21]. Buprenorphine undergoes hepatic metabolism primarily by the enzyme CYP3A4, which converts about 30% of it to norbuprenorphine. Norbuprenorphine acts as a weak agonist at mu (μ), kappa (κ), delta (δ), and nociceptin receptors. Subsequently, it combines with glucuronic acid to form the inactive metabolites buprenorphine-3-glucuronide and norbuprenorphine-3-glucuronide. Norbuprenorphine has an analgesic effect that is approximately 40 times weaker than that of buprenorphine and has significantly lower lipophilicity. Buprenorphine passes through

the blood–brain barrier more weakly. The concurrent use of drugs that induce or inhibit CYP 3A4 may affect the efficacy and effects of buprenorphine by reducing or increasing its analgesic effect [32]. Both buprenorphine and its metabolites are excreted via bile into the gastrointestinal tract, with approximately 70% of the drug being eliminated unchanged. The remainder is excreted through urine. In patients with hepatic insufficiency, both the duration and potency of buprenorphine may be altered. Therefore, carefully monitoring these patients for any adverse or toxic effects is essential [31].

In contrast, the pharmacokinetics of buprenorphine remain unchanged in individuals with renal failure, allowing for the drug to be safely used in this group. Clinical trials have demonstrated that buprenorphine is not removed from the body during hemodialysis. Additionally, no dosage modifications are necessary for elderly patients [31].

Analgesic efficacy and safety of buprenorphine in pain management

The analgesic efficacy of buprenorphine has been assessed in various studies, including experimental and clinical research. In a study conducted by Curtin et al. on postoperative pain in rats, it was demonstrated that administering a dose of 0.05 mg/kg increased the pain threshold and reduced levels of allodynia and hyperalgesia at the injury site. The analgesic effect was directly proportional to the administered dose and lasted for up to 8 h [33]. Many researchers suggest that buprenorphine is more effective than other opioids and tricyclic antidepressants in inhibiting allodynia and hyperalgesia associated with both mono- and polyneuropathic pain [34–36]. Numerous studies have highlighted its benefits and significant analgesic potential for this type of pain [37–39].

Buprenorphine is an effective pain reliever for treating bone pain and is more effective than morphine or fentanyl [40–42]. Additionally, in cases of thermal burns, buprenorphine modifies the body's hemodynamic response to injury, making it a suitable choice for managing pain in extensive burns [43].

Both randomized observational studies and systematic reviews indicate that buprenorphine, in comparison to other opioid analgesics, provides effective analgesic relief for patients experiencing moderate to severe pain, regardless of its cause [44–49]. n a study conducted by Gatti et al., it was found that buprenorphine effectively relieved musculoskeletal pain in 47% of subjects, improving the quality of life for the treated patients [50].

The use of buprenorphine for pain management also enhances sleep quality in patients whose pain disrupts their sleep. Improvements in sleep quality were noted within 4 weeks of initiating buprenorphine in a transdermal system [51].

Buprenorphine displays effects similar to those of local anesthetic drugs. When added to ropivacaine for subarachnoid administration, it has been proven to extend the duration of sensory blockade significantly. Similar effects have been observed in brachial plexus blockades. This prolongation allows for a considerable delay between the onset of the blockade and the need to administer a systemic analgesic [52–54].

Patanwala et al. demonstrated that buprenorphine, in its buccal form, is an effective analgesic for treating pain in patients hospitalized in intensive care units, and its efficacy is comparable to that of oxycodone [55].

Clinical studies examining the safety of buprenorphine primarily focus on its effects on the respiratory, gastrointestinal, central nervous, endocrine, and immune systems. Additionally, the development of opioid-induced tolerance and hyperalgesia is a significant consideration. In these studies, the overall incidence of side effects associated with buprenorphine use is estimated to be between 20 and 32% [56, 57]. The main side effects of this drug are similar to those of other mu receptor agonists (μ), but their severity is generally much less than that of pure agonists [58]. In a published article, Davis MP highlighted the safety advantages of buprenorphine compared to other opioids [59].

Buprenorphine is considered one of the safest opioid analgesics in clinical practice, primarily due to its ceiling effect on respiratory depression, as noted by experts [37, 59–62]. Research indicates that 1–11% of patients receiving opioid treatment experience symptoms of respiratory depression, with the risk being more pronounced in individuals who are obese, elderly, or have obstructive sleep apnea or neuromuscular conditions [58]. Experimental studies suggest that respiratory depression linked to buprenorphine is caused by its metabolite, norbuprenorphine, rather than by buprenorphine itself. Notably, buprenorphine has been shown to prevent and reverse respiratory depression in experimental rats that were administered a lethal dose of norbuprenorphine [63]. Additionally, studies have demonstrated that buprenorphine is significantly safer (13,5 times) compared to fentanyl (1,2 times) at both analgesic and respiratory-inducing doses in laboratory rats [64]. It is important to note that combining buprenorphine with benzodiazepines or alcohol can negatively impact the respiratory system by worsening respiratory depression. However, the combination of buprenorphine with benzodiazepines is believed to be safer than combining methadone with benzodiazepines [65].

Numerous studies indicate that buprenorphine has a low potential for causing constipation, with occurrence rates ranging from 1 to 5%. This is in contrast to pure μ-opioid receptor agonists, which are more likely

to induce constipation. The reduced risk is likely due to buprenorphine's limited effect on μ-opioid receptors located in the gastrointestinal wall [38, 66, 67]. Additionally, buprenorphine does not induce contraction of the sphincter of Oddi, making it a safe and effective choice for managing biliary colic and pancreatitis [68].

Buprenorphine, like other opioids, can impair cognitive function and driving ability. These impairments are particularly noticeable when buprenorphine is combined with alcohol or sedatives. They may also occur at the beginning of treatment or when the drug dosage is adjusted. Comparative studies have shown that buprenorphine has minor negative effects on visual, cognitive, and psychomotor functions when compared to morphine, fentanyl, and methadone. In many cases, the effects were found to be comparable to those of a placebo [59, 69, 70].

Opioids play a role in biochemical communication between the brain and the immune system. Numerous studies have shown that exogenous (externally administered) opioids suppress the immune system, while endogenous (naturally occurring) opioids stimulate it. The immunosuppressive effects of opioids are particularly significant during the postoperative period, when both pain and susceptibility to infection are heightened. Similar effects are observed in patients with chronic pain, elderly individuals, those who have undergone organ transplantation, and patients with compromised immune systems, such as those living with HIV [71].

Strong opioid pain relievers like morphine and fentanyl impair antibody production, reduce natural killer (NK) cell activity, decrease cytokine expression, and lower leukocyte phagocytic activity. The immunosuppressive effects are amplified by corticosteroids and immunosuppressants [59, 72]. Compared to morphine, buprenorphine does not influence natural killer (NK) cell activity, nor does it increase cortisol levels or reduce adrenocorticotropic hormone (ACTH) levels. Additionally, buprenorphine does not affect the levels of norepinephrine or serotonin in the central nervous system. It also has a significantly lower impact on the function of the gonads, hypothalamus, and pituitary gland. As a result, its use is less likely to lead to hypogonadism or symptoms associated with sex hormone deficiency [72, 73]. In contrast to morphine and fentanyl, which can lower testosterone levels, buprenorphine—even at high doses—has no significant effect on sex hormone levels [37, 59, 74, 75].

Buprenorphine substitution therapy carries a potential risk of arrhythmias, specifically by prolonging the QT interval on an ECG. This prolongation can lead to the development of torsades de pointes. The most likely reason for this phenomenon is buprenorphine's inhibitory effect on sodium channels. Scientific reports indicate that the risk of torsades de pointes or sudden cardiac death with methadone is four times greater than that associated with buprenorphine used as a substitution treatment [76–80].

Numerous studies conducted on patients over the age of 65 have demonstrated that dosage adjustments for buprenorphine are not necessary. This is attributed to the drug's stable pharmacokinetic profile, efficacy, and safety. Common medications that inhibit CYP3A4, which are frequently used by elderly patients, do not seem to impact the pharmacokinetics of buprenorphine. Additionally, glucuronidation significantly minimizes the potential for drug interactions [21, 37, 81].

Buprenorphine is a safe alternative for treating acute postoperative pain in patients with renal failure, including those on dialysis. Although it is primarily eliminated through bile in the gastrointestinal tract, it also appears relatively safe for patients with liver failure [82–85].

Table 2 presents the safety profile of buprenorphine compared to other opioid analgesics.

Results of observations and experiences with the pain management team at copernicus hospital

Buprenorphine is one of the opioid analgesics available for intravenous delivery to patients at Copernicus Hospital undergoing various surgical procedures, including orthopedics and traumatology, general surgery,

Table 2 Comparison of the safety profiles of buprenorphine and other opioid analgesics

Opioid	Respiratory depression	Sedation	Constipation	Impact on the immune system	Development of tolerance	Addiction	Hyperalgesia
Moprhine	High risk	High risk	High risk	High	Moderately high	Possible	Possible
Hydromorphn	High risk	High risk	-	-	Risk unknown	Possible	-
Methadone	High risk	-	-	Unknow	Risk unknown	-	-
Oxynorm	High risk	High risk	High risk	-	Moderately high	Possible	-
Fentanyl	High risk	High risk	Moderate risk	High	Moderately high	-	Possible
Buprenorphine	Moderate risk	Low risk	Moderate risk	-	Risk unknown	Limited risk	Anti-hyperalgia action

neurosurgery, spinal surgery, gynecology, and otorhinolaryngology. The use of this medication in injectable form is permitted only by medical order. When administered in individually tailored doses, buprenorphine provides rapid, effective, and safe relief from acute postoperative pain, particularly during the first 24–48 h when pain intensity is typically highest. Its pharmacodynamic and pharmacokinetic properties make it suitable for patients who do not require intensive care or continuous monitoring of vital parameters, yet experience moderate to severe pain. In 2024, approximately 500 patients at Copernicus Hospital received buprenorphine in solution form during their surgeries. Established guidelines used the drug for treating acute postoperative pain as part of a multimodal approach, with typical doses ranging from 0.3 to 0.6 mg every 6–8 h. This regimen resulted in effective postoperative analgesia, with patients reporting an average pain rating of 0–1 point on the Numeric Rating Scale (NRS).

When using buprenorphine for opioid analgesic management, complications such as nausea, vomiting, and increased drowsiness were observed in 10% (50 patients) of the study group. These side effects were linked to excessively high doses of the drug relative to the patients' weight and age. Importantly, there were no cases of respiratory depression or other typical opioid side effects reported. Patients for whom buprenorphine was the first-line opioid analgesic reported satisfactory pain control, which enabled effective early motor rehabilitation and mobilization in 90% (450 patients) of the group. This was crucial for improving the overall clinical outcomes of the treatment. Furthermore, the use of buprenorphine in a multimodal pain management approach led to a reduction in the frequency and dosage of analgesics used. This, in turn, minimized the adverse effects of analgesic treatment, including a decreased risk of gastrointestinal bleeding associated with nonsteroidal analgesics.

Buprenorphine has a lower risk of developing tolerance compared to other opioids, which is an important consideration for patients needing prolonged analgesic therapy.

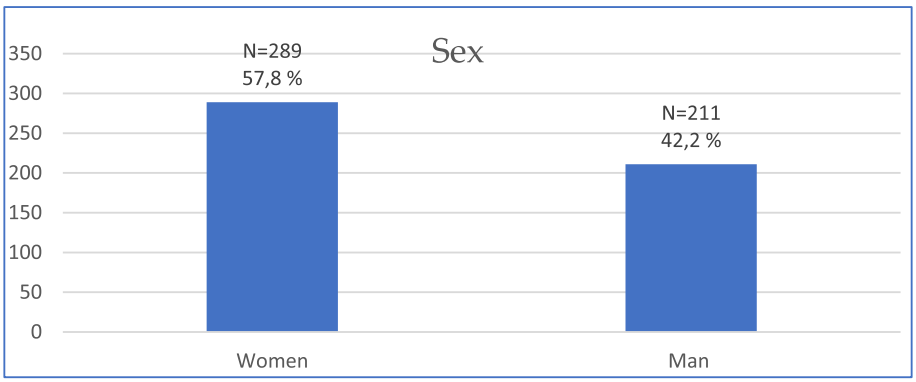

Fig. 1 Analysis of buprenorphine-treated patients by gender

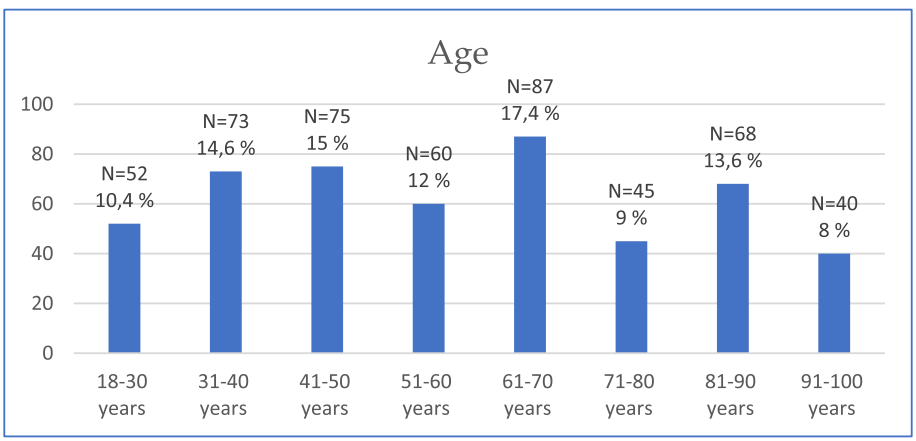

Fig. 2 Classification of patients based on age

The following text presents the most relevant data regarding the use of buprenorphine, illustrated through graphs. The data includes demographic information (Fig. 1 and 2), the number of patients in each hospital department who received buprenorphine for postoperative analgesia (Fig. 3), and a breakdown of the patients according to the surgical procedures performed (Fig. 4). Additionally, it includes pain intensity scores on the Numeric Rating Scale (NRS) both before and after administering the drug (Fig. 5 and 6). The average duration of buprenorphine use as part of a multimodal analgesia approach (Fig. 7), along with the drug's side effects, is also provided (Fig. 8).

Buprenorphine, administered intravenously for the treatment of acute postoperative pain at Copernicus Hospital, has proven to be an effective and safe method of analgesia. It provided satisfactory pain control with low side effects, leading to higher patient satisfaction and faster recovery. Our experience confirms that buprenorphine is a valuable alternative in the modern, comprehensive management of acute postoperative pain.

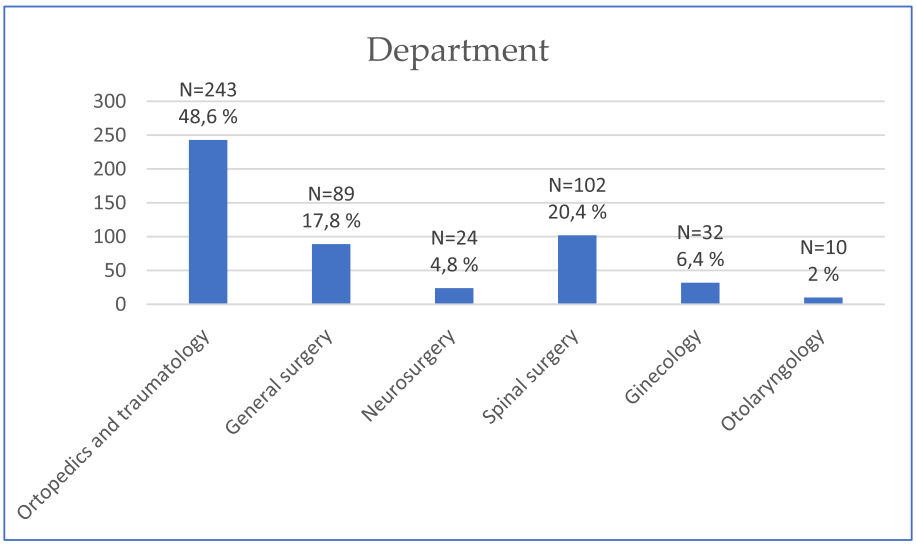

Fig. 3 The number of patients admitted to each hospital department who received postoperative analgesia with buprenorphine

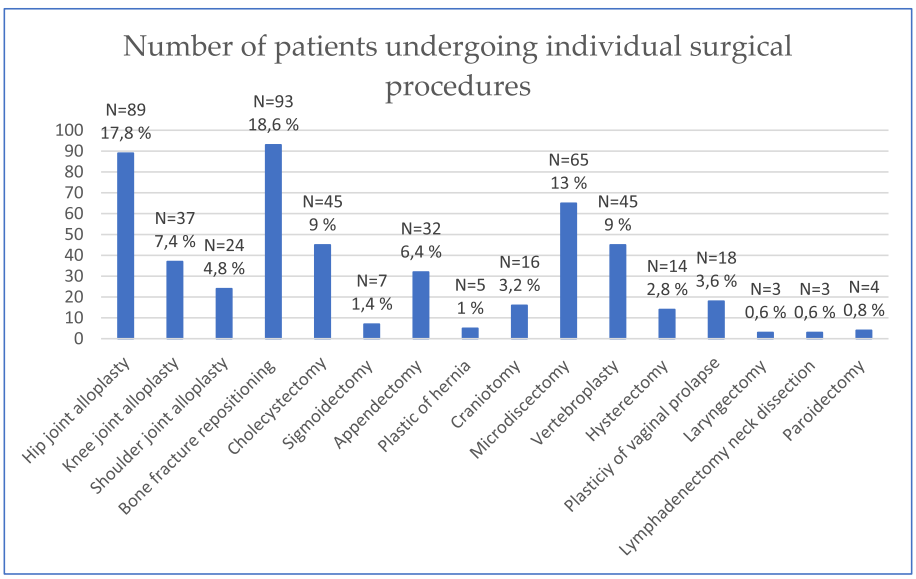

Fig. 4 Classification of patients based on the surgery performed, in which buprenorphine was used for postoperative analgesia

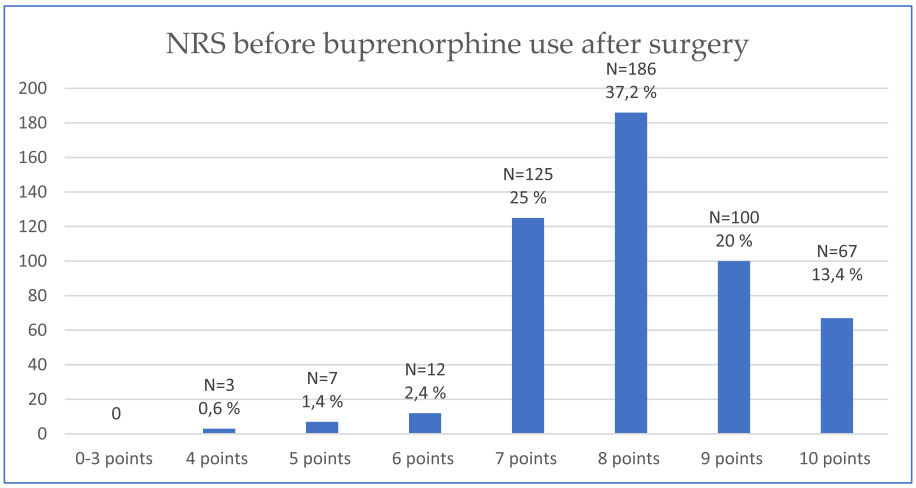

Fig. 5 Assessment of pain intensity on the numeric rating scale (NRS) before the use of buprenorphine

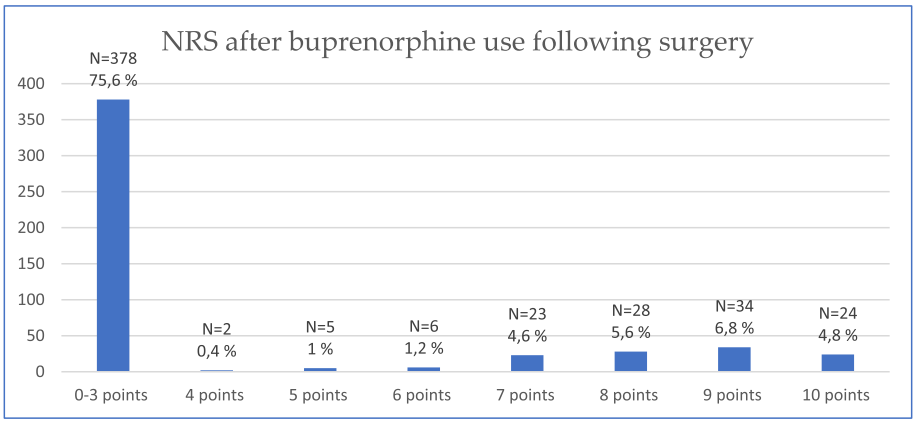

Fig. 6 Assessment of pain intensity on the numeric rating scale (NRS) after the use of buprenorphine

Discussion

Buprenorphine is a mild analgesic opioid that falls under the category of partial mu (μ) receptor agonists. The drug is available in several forms, including a transdermal system, lozenge tablets, and an injectable solution. In 1982, the FDA approved the injectable solution for treating acute pain of moderate to severe intensity. This solution is designed for intramuscular delivery or slow intravenous injection. Buprenorphine is provided as a clear liquid, containing 0.3 mg of the drug per milliliter. It reaches its maximum plasma concentration within 5 to 15 min, with a duration of action estimated to last 6 h or more [86]. A literature review by Hale et al. confirms that intravenous buprenorphine is effective for pain relief, showing comparable or superior efficacy to morphine in managing postoperative pain [87].

Posso-Sierra et al. reported on the evaluation of the analgesic efficacy of buprenorphine in treating acute postoperative pain in patients who have undergone thoracic surgery. They highlight the importance of buprenorphine in pain management. The study indicates that a multimodal approach to pain treatment following thoracoscopic surgery helps to reduce pain intensity. Buprenorphine, administered at doses of 1 to 3 μg/kg body weight, does not cause nausea, vomiting, rash, or respiratory depression. The researchers found that using buprenorphine at doses of 2 and 3 μg/kg body weight allows for better pain control, resulting in more effective analgesia [88].

Buresh et al. noted that treating acute postoperative pain in patients who have been using buprenorphine chronically requires a multimodal approach to pain management. Discontinuing buprenorphine before scheduled surgery could expose the patient to unnecessary costs, as they would need to restart buprenorphine

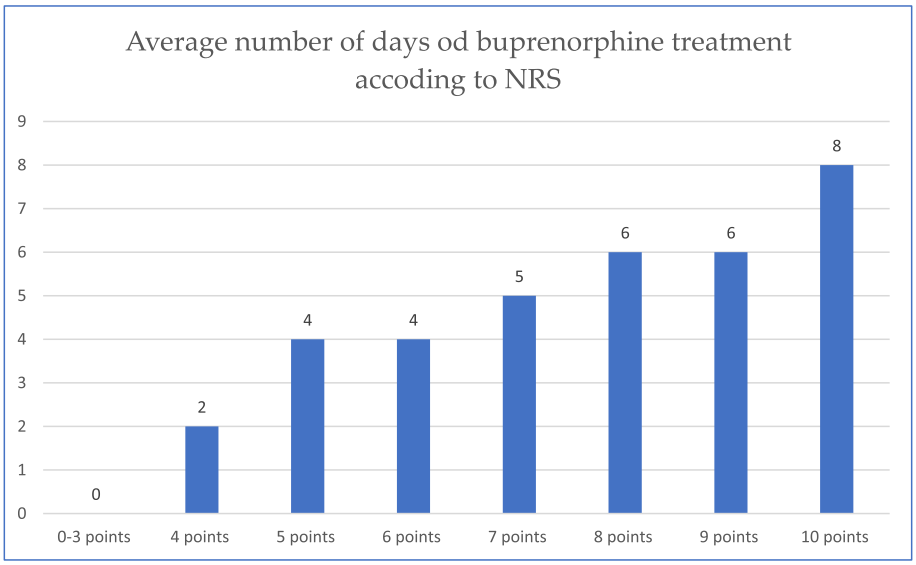

Fig. 7 The average duration of buprenorphine use in multimodal pain treatment

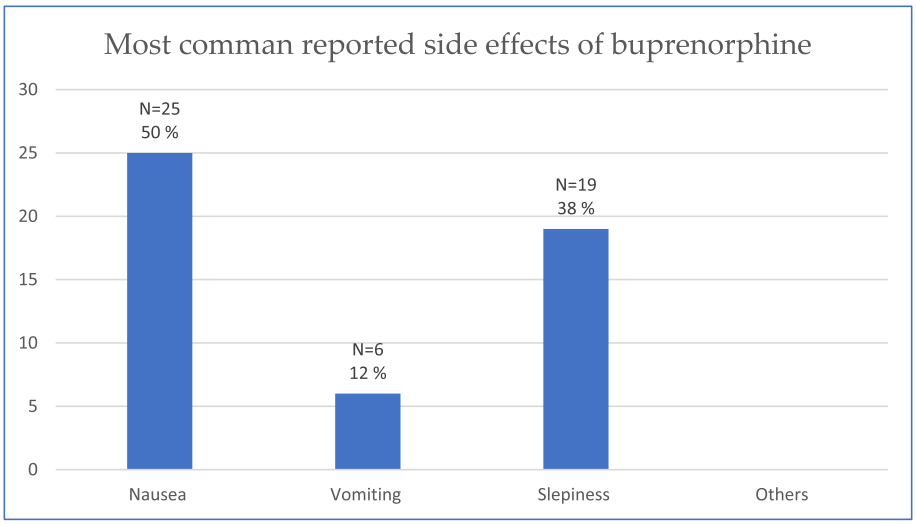

Fig. 8 The occurrence of adverse reactions related to the use of buprenorphine

treatment if they require ongoing opioid analgesics for health reasons [89].

In their paper titled "Buprenorphine for Acute Post-Surgical Pain: A Systematic Review and Meta-Analysis," Albaqami et al. reviewed 15 studies. The authors concluded that buprenorphine, whether administered in transdermal or sublingual form, is effective for pain relief. This effectiveness can reduce reliance on other analgesics [90].

The pharmacokinetic and pharmacodynamic characteristics of buprenorphine make it an effective and safe option for managing acute postoperative pain. These attributes ensure patient safety in surgical ward settings.

Conclusion

Buprenorphine is a safe and effective opioid analgesic. Its pharmacokinetic and pharmacodynamic characteristics make it suitable for use in patients of all ages, including those with renal and liver failure, without significantly increasing the risk of respiratory depression or complications related to these conditions. The drug is beneficial for managing acute postoperative pain as an alternative to other opioid analgesics. Its favorable safety profile allows for substantial pain relief in postoperative patients who do not require intensive monitoring of vital signs but are still hospitalized in surgical units.

Abbreviations

μ	Mu opioid receptor
κ	Kappa opioid receptor
δ	Delta opioid receptor
KARs	Kainate ionotropic receptors
AMPA	Amino-3-hydroxy-5-methyl-4-isoxazolopropionic acid
NMDA	N-methyl-D-aspartate
HPA	Hypothalamic-pituitary-adrenocortical axis
Bw	Body weight
mg/kg	Milligram/kilogram
CYP 3A4	Cytochrome 3A4
HIV	Human immunodeficiency virus
NK	Natural killer
ACTH	Adrenocorticotropic hormone
ECG	Electrocardiography
NRS	Numeric Rating Scale
FDA	Food and Drug Administration
μg/kg	Microgram/kilogram

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