

## Original Research

Received 03 June 2026

Revised 22 July 2026

Accepted 04 August 2026

Natural Resources for Human Health  
2026, Vol. 6 (14s): 1448–1460

### KEYWORDS:

Anesthetic Technique; Postoperative Recovery; Multimodal Analgesia; Regional Anesthesia; Total Intravenous Anesthesia; ERAS; Opioid Stewardship; Saudi Arabia; Vision 2030

## The Effect of Anesthetic Techniques on Postoperative Recovery and Pain Management: An Evidence-Based Review and the RESTORE Framework for Recovery-Oriented Anesthesia Practice in the Kingdom of Saudi Arabia

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### ABSTRACT:

**Background:** The choice of anesthetic technique is no longer judged solely by intraoperative stability; it is increasingly evaluated by its influence on the quality, speed, and safety of postoperative recovery. Pain, postoperative nausea and vomiting (PONV), delirium, delayed mobilization, and persistent opioid use remain major contributors to patient dissatisfaction, prolonged hospital stay, and avoidable cost.

**Objective:** This paper critically reviews contemporary evidence on how general anesthesia (volatile and total intravenous), neuraxial anesthesia, peripheral and fascial plane blocks, monitored anesthesia care, and opioid-sparing strategies affect postoperative recovery and pain outcomes, and translates this evidence into a practical framework for Saudi healthcare institutions.

**Methods:** A structured narrative review of randomized controlled trials, systematic reviews, meta-analyses, and international consensus guidelines was conducted, interpreted through Donabedian's structure–process–outcome model, Enhanced Recovery After Surgery (ERAS) principles, and the biopsychosocial model of pain.

**Findings:** Propofol-based total intravenous anesthesia consistently reduces PONV and improves early recovery quality; regional and neuraxial techniques provide superior dynamic analgesia and reduce opioid consumption, although their effects on mortality, delirium, and cancer recurrence are smaller than once assumed. Multimodal, procedure-specific analgesia embedded within ERAS pathways offers the most reliable benefit.

**Conclusion:** No single technique is universally superior. Recovery-oriented anesthesia requires individualized technique selection, systematic outcome measurement, and institutional governance. The proposed RESTORE framework offers a structured pathway for Saudi hospitals to achieve these goals in line with Vision 2030.

## 1. INTRODUCTION

More than 300 million surgical procedures are performed worldwide each year, and nearly every one of them depends on an anesthetic technique chosen by an anesthesia team. For much of the twentieth century, the success of anesthesia was defined narrowly: the patient did not move, did not remember, remained hemodynamically stable, and woke up safely. Over the past three decades, however, the focus of perioperative medicine has shifted decisively from the operating room to the days and

weeks that follow surgery. Patients, payers, and health systems now ask a broader question: how well, how quickly, and how comfortably does the patient recover?

This shift reflects several converging developments. The growth of ambulatory and same-day surgery has made rapid emergence, early ambulation, and freedom from nausea essential rather than desirable. Enhanced Recovery After Surgery (ERAS) programs have demonstrated that coordinated perioperative bundles can shorten hospital stays and reduce complications (Ljungqvist et al., 2017). At the same time, the global opioid crisis has revealed that postoperative prescribing is an important gateway to persistent opioid use, with new long-term use reported in a meaningful proportion of previously opioid-naïve surgical patients (Brummett et al., 2017). Finally, the recognition that acute postoperative pain can transition into chronic post-surgical pain has transformed analgesia from a comfort measure into a long-term health issue (Kehlet et al., 2006).

Against this background, the anesthetic technique has emerged as a modifiable determinant of postoperative outcomes. Decisions such as whether to use a volatile agent or propofol, whether to add a neuraxial or peripheral nerve block, how much intraoperative opioid to administer, and which adjuncts to include all shape the patient's pain trajectory, nausea risk, cognitive recovery, and functional return. Yet the evidence is nuanced, occasionally contradictory, and frequently misinterpreted in practice.

In the Kingdom of Saudi Arabia, these questions carry particular weight. The Health Sector Transformation Program under Vision 2030 emphasizes value-based care, patient experience, efficiency, and measurable quality. Surgical volumes are rising alongside an ageing population and a high prevalence of obesity and diabetes, both of which complicate anesthetic management and recovery. Institutions accredited by the Saudi Central Board for Accreditation of Healthcare Institutions (CBAHI) are expected to demonstrate structured pain management and patient safety processes, while the Saudi Food and Drug Authority (SFDA) regulates controlled analgesics.

This paper therefore has four aims: **(1)** to summarize the major anesthetic techniques and their mechanisms of influence on recovery; **(2)** to critically appraise the evidence linking these techniques to key recovery and pain outcomes; **(3)** to examine considerations for special populations and the Saudi healthcare context; and **(4)** to propose the RESTORE framework, an original, implementation-oriented model for recovery-focused anesthesia practice.

## 2. THEORETICAL AND CONCEPTUAL FOUNDATIONS

### 2.1 Donabedian's Structure–Process–Outcome Model

Donabedian (1988) proposed that quality of care can be evaluated through three linked dimensions: structure (the resources, equipment, staffing, and organizational arrangements), process (what is actually done in delivering care), and outcome (the resulting change in the patient's health status). This model is highly applicable to anesthetic practice. Structural elements include the availability of ultrasound machines for regional anesthesia, target-controlled infusion pumps, acute pain services, and trained staff. Process elements include risk stratification, technique selection, adherence to PONV prophylaxis guidelines, and multimodal analgesic prescribing. Outcomes include pain scores, opioid consumption, PONV incidence, delirium, length of stay, readmission, and patient-reported quality of recovery. The model reminds clinicians that improving outcomes rarely depends on a single drug choice; it depends on aligning structures and processes.

### 2.2 Enhanced Recovery After Surgery (ERAS)

ERAS is a multimodal, evidence-based perioperative care philosophy that seeks to reduce the surgical stress response, maintain physiological function, and accelerate recovery (Ljungqvist et al., 2017). Anesthesia contributes several core ERAS elements: short-acting anesthetic agents, avoidance of long-acting sedative premedication, goal-directed fluid management, normothermia, PONV prophylaxis, regional analgesia where appropriate, and opioid-sparing multimodal analgesia. Within ERAS, the anesthetic technique is not an isolated decision but one component of a coordinated bundle, and its benefits are amplified when the full pathway is implemented with high compliance.

### 2.3 The Biopsychosocial Model of Pain

Engel's (1977) biopsychosocial model holds that illness experience arises from the interaction of biological, psychological, and social factors. Postoperative pain illustrates this well. Tissue injury and inflammation drive peripheral and central sensitization, but anxiety, catastrophizing, prior chronic pain, expectations, cultural beliefs about pain expression, and family support all shape pain intensity and analgesic requirements. Anesthetic techniques act primarily on the biological dimension, yet preoperative

education, expectation management, and psychological screening can magnify or diminish their effect. This model underpins the argument that pain management must be individualized rather than protocol-driven alone.

## 2.4 Systems Safety and Reason's Swiss Cheese Model

Reason's (2000) Swiss cheese model conceptualizes adverse events as the result of aligned weaknesses across multiple layers of defense. Postoperative complications such as respiratory depression from opioids, falls from motor block, or unrecognized local anesthetic systemic toxicity rarely stem from one error. They reflect gaps in assessment, prescribing, monitoring, handover, and escalation. Recovery-oriented anesthesia must therefore embed safety layers such as standardized order sets, sedation scoring, capnography for high-risk patients, and lipid emulsion availability wherever regional anesthesia is performed.

## 3. OVERVIEW OF ANESTHETIC TECHNIQUES

Anesthetic techniques can be broadly grouped into general anesthesia, neuraxial anesthesia, peripheral and fascial plane regional techniques, and monitored anesthesia care with sedation. In modern practice these categories are frequently combined, for example general anesthesia with an epidural catheter, or spinal anesthesia with a supplementary nerve block and light sedation. The following subsections describe each approach and its principal mechanisms of influence on recovery.

### 3.1 General Anesthesia: Volatile Versus Total Intravenous Anesthesia

General anesthesia may be maintained with inhaled volatile agents, most commonly sevoflurane or desflurane, or with total intravenous anesthesia (TIVA), typically a propofol infusion combined with remifentanyl or another opioid. Volatile agents are simple to administer, inexpensive, and allow end-tidal concentration monitoring. However, they are a well-established independent risk factor for PONV, with a dose-dependent effect most pronounced in the early postoperative hours (Apfel et al., 2004). Propofol-based TIVA is associated with a lower incidence of PONV, smoother emergence, and, in several studies, higher patient satisfaction and improved early quality of recovery. A systematic review and meta-analysis comparing propofol with inhalational agents found a significant reduction in PONV with propofol maintenance, alongside comparable or improved recovery characteristics (Schraag et al., 2018). The principal limitations of TIVA include the need for infusion pumps, a higher risk of accidental awareness if delivery is interrupted without processed electroencephalographic monitoring, and greater requirement for training. Environmental considerations are increasingly relevant, since volatile agents, particularly desflurane, are potent greenhouse gases.

### 3.2 Neuraxial Anesthesia

Neuraxial techniques include spinal (subarachnoid) anesthesia, epidural anesthesia and analgesia, and combined spinal–epidural approaches. By blocking afferent nociceptive transmission and attenuating the neuroendocrine stress response, neuraxial anesthesia offers dense surgical anesthesia with minimal systemic drug exposure. Thoracic epidural analgesia has historically been the gold standard for major open abdominal and thoracic surgery, providing excellent dynamic pain relief, improved pulmonary function, and earlier return of bowel function. Early meta-analyses suggested reductions in mortality and major morbidity with neuraxial blockade (Rodgers et al., 2000), although these findings were derived largely from older trials conducted before contemporary perioperative care.

The disadvantages of neuraxial techniques include hypotension, urinary retention, pruritus with neuraxial opioids, motor block that may delay mobilization, rare but serious complications such as epidural hematoma or abscess, and contraindications in patients receiving anticoagulants. With the increasing use of minimally invasive and laparoscopic surgery, the relative benefit of thoracic epidurals has diminished, and many ERAS programs now favor alternative techniques for laparoscopic procedures.

### 3.3 Peripheral Nerve and Fascial Plane Blocks

The widespread adoption of ultrasound guidance has transformed peripheral regional anesthesia. Plexus and peripheral nerve blocks, such as interscalene, supraclavicular, femoral, adductor canal, and popliteal sciatic blocks, provide targeted analgesia for limb surgery with reduced opioid consumption and high patient satisfaction. More recently, fascial plane blocks, including the transversus abdominis plane (TAP), erector spinae plane (ESP), quadratus lumborum, and pectoral nerve blocks, have expanded regional options for truncal surgery (Albrecht & Chin, 2020). Their evidence base is heterogeneous: some blocks show robust opioid-sparing effects for specific procedures, while others show modest or inconsistent benefit, underscoring the importance of procedure-specific evidence.

## 3.4 Monitored Anesthesia Care and Sedation

Monitored anesthesia care (MAC) combines local or regional anesthesia with titrated sedation. It is increasingly used for endoscopic, ophthalmic, interventional, and minor surgical procedures. MAC avoids airway instrumentation and deep anesthesia, enabling rapid discharge, yet it carries risks of oversedation, airway obstruction, and hypoventilation, particularly in patients with obesity or obstructive sleep apnea. Safe MAC requires the same standards of monitoring, including capnography, as general anesthesia.

## 3.5 Opioid-Sparing and Opioid-Free Anesthesia

Opioid-sparing anesthesia uses non-opioid adjuncts such as ketamine, dexmedetomidine, lidocaine infusion, magnesium, and dexamethasone to reduce intraoperative opioid requirements. Opioid-free anesthesia (OFA) eliminates intraoperative opioids entirely. The rationale is to reduce opioid-induced hyperalgesia, PONV, respiratory depression, and ileus. However, the multicenter POFA trial found that a dexmedetomidine-based opioid-free regimen did not reduce the composite of postoperative opioid-related adverse events compared with remifentanyl-based anesthesia and was associated with more hypoxemia and bradycardia (Beloil et al., 2021). These findings suggest that opioid sparing is a sound principle, but that complete opioid avoidance should not be pursued dogmatically.

**Table 1.** Comparison of Major Anesthetic Techniques and Their Influence on Recovery

| Technique                                | Key Agents / Approach                                  | Recovery Advantages                                            | Limitations and Risks                                                 |
|------------------------------------------|--------------------------------------------------------|----------------------------------------------------------------|-----------------------------------------------------------------------|
| <b>Volatile-based GA</b>                 | Sevoflurane, desflurane, isoflurane                    | Simple titration; end-tidal monitoring; low cost               | Higher PONV risk; greenhouse gas impact; possible emergence agitation |
| <b>Propofol TIVA</b>                     | Propofol $\pm$ remifentanyl via TCI or manual infusion | Lower PONV; smoother emergence; improved early QoR             | Pump dependence; awareness risk without processed EEG; training needs |
| <b>Neuraxial anesthesia</b>              | Spinal, epidural, combined spinal–epidural             | Dense analgesia; reduced stress response; less systemic opioid | Hypotension; urinary retention; motor block; anticoagulation limits   |
| <b>Peripheral / fascial plane blocks</b> | Adductor canal, interscalene, TAP, ESP, QL blocks      | Targeted opioid-sparing analgesia; early mobilization          | Block failure; limited duration; LAST; variable evidence by block     |
| <b>Monitored anesthesia care</b>         | Local/regional + titrated sedation                     | Rapid discharge; avoids airway instrumentation                 | Oversedation; airway obstruction in OSA/obesity                       |
| <b>Opioid-sparing / opioid-free</b>      | Ketamine, dexmedetomidine, lidocaine, magnesium        | Less PONV and opioid exposure; lower hyperalgesia risk         | Bradycardia, hypoxemia (dexmedetomidine); heterogeneous evidence      |

*Note.* GA = general anesthesia; TIVA = total intravenous anesthesia; TCI = target-controlled infusion; QoR = quality of recovery; TAP = transversus abdominis plane; ESP = erector spinae plane; QL = quadratus lumborum; LAST = local anesthetic systemic toxicity; OSA = obstructive sleep apnea.

## 4. IMPACT OF ANESTHETIC TECHNIQUES ON POSTOPERATIVE RECOVERY

Postoperative recovery is a multidimensional process encompassing physiological, nociceptive, emotional, functional, cognitive, and social domains. It is commonly described in three phases: early recovery (from the end of anesthesia to discharge from the post-anesthesia care unit), intermediate recovery (to hospital discharge or readiness for discharge), and late recovery (return to

baseline function and daily activities). Traditional instruments such as the Aldrete score (Aldrete, 1995) assess readiness for PACU discharge, whereas patient-reported outcome measures such as the Quality of Recovery-15 (QoR-15) capture the patient's perspective across multiple domains (Stark et al., 2013).

## 4.1 Postoperative Nausea and Vomiting

PONV affects approximately 30% of surgical patients overall and up to 80% of high-risk patients without prophylaxis. It is among the most distressing experiences reported by patients, often ranked as worse than pain, and it delays discharge, increases costs, and can lead to wound dehiscence or aspiration. In a landmark factorial trial of more than 5,000 patients, Apfel et al. (2004) demonstrated that propofol TIVA, avoidance of nitrous oxide, and antiemetics such as ondansetron and dexamethasone each reduced PONV by roughly a quarter, and that their effects were largely additive. The Fourth Consensus Guidelines recommend risk assessment using validated scores, reduction of baseline risk through strategies such as TIVA and opioid sparing, and multimodal prophylaxis with at least two antiemetics for patients with risk factors (Gan et al., 2020).

*"The anesthetic technique is not merely the way a patient is put to sleep; it is the first intervention in the patient's recovery."*

## 4.2 Postoperative Delirium and Neurocognitive Recovery

Postoperative delirium is an acute disturbance of attention and cognition that commonly affects older adults after major surgery and is associated with longer hospital stays, functional decline, institutionalization, and increased mortality. The 2018 nomenclature recommendations reclassified postoperative cognitive changes under the umbrella of perioperative neurocognitive disorders (Evered et al., 2018). It was long hypothesized that avoiding general anesthesia through neuraxial techniques would reduce delirium. However, the REGAIN trial, involving 1,600 older adults undergoing hip fracture surgery, found no significant difference between spinal and general anesthesia in the composite of death or inability to walk at 60 days, nor in the incidence of delirium (Neuman et al., 2021). Similarly, the RAGA trial found no significant reduction in delirium with regional compared with general anesthesia in older patients with hip fractures (Li et al., 2022).

These findings shift attention from the choice of technique itself to modifiable perioperative factors: avoiding excessive anesthetic depth, minimizing benzodiazepines and anticholinergic drugs, ensuring adequate analgesia, preventing hypotension, preserving sleep, encouraging early mobilization, and involving family members in orientation. Processed EEG-guided anesthesia remains a subject of ongoing research, with mixed results on delirium prevention.

## 4.3 Gastrointestinal Function and Mobilization

Postoperative ileus is a major barrier to recovery after abdominal surgery. Opioids inhibit gastrointestinal motility, whereas thoracic epidural analgesia with local anesthetics blocks sympathetic outflow and has been shown to accelerate return of bowel function after open abdominal surgery. Intravenous lidocaine infusion may provide similar benefits in selected settings. Early mobilization, a cornerstone of ERAS, depends on effective dynamic analgesia without significant motor block. This explains the shift in knee arthroplasty from femoral nerve blocks, which weaken the quadriceps, to motor-sparing adductor canal blocks that preserve mobility while maintaining analgesia.

## 4.4 Length of Stay, Complications, and Mortality

Length of hospital stay is a composite outcome influenced by surgical, anesthetic, and organizational factors. Regional anesthesia and TIVA can contribute to shorter stays by reducing PONV, pain, and opioid-related adverse effects, particularly in ambulatory surgery. However, the impact of anesthetic technique on major complications and mortality is less certain than earlier literature implied. A Cochrane review of anesthesia for hip fracture surgery found no clear difference in mortality between regional and general anesthesia (Guay et al., 2016). A systematic update by Liu and Wu (2007) concluded that effective postoperative analgesia, particularly epidural analgesia, may reduce pulmonary complications, but that the evidence for mortality benefit was not conclusive.

**Table 2.** Recovery Domains, Measurement Tools, and Summary of Evidence

| Recovery Domain                     | Common Measures                                         | Summary of Evidence by Technique                                                                                  |
|-------------------------------------|---------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| <b>PONV</b>                         | Apfel risk score; PONV incidence; rescue antiemetic use | Propofol TIVA, opioid sparing, and multimodal prophylaxis consistently reduce PONV; volatile agents increase risk |
| <b>Pain intensity</b>               | NRS/VAS at rest and on movement                         | Regional and neuraxial techniques provide superior dynamic analgesia in the first 24–48 hours                     |
| <b>Opioid consumption</b>           | Morphine milligram equivalents (MME)                    | Blocks, neuraxial analgesia, and non-opioid adjuncts reduce opioid use; magnitude varies by procedure             |
| <b>Delirium / cognition</b>         | CAM, 4AT, neurocognitive testing                        | Large RCTs show no clear advantage of regional over general anesthesia; perioperative bundle factors matter most  |
| <b>Bowel function</b>               | Time to flatus, tolerance of diet                       | Thoracic epidural and lidocaine infusion accelerate return after open abdominal surgery                           |
| <b>Mobilization and LOS</b>         | Time to ambulation; length of stay                      | Motor-sparing blocks and ERAS bundles shorten stay; effects of technique alone are modest                         |
| <b>Patient-reported recovery</b>    | QoR-15; satisfaction scores                             | TIVA and regional analgesia are associated with higher early QoR scores in several trials                         |
| <b>Persistent postsurgical pain</b> | Pain at 3–6 months                                      | Regional anesthesia may reduce chronic pain after selected procedures such as thoracotomy and breast surgery      |

*Note.* NRS = *numeric rating scale*; VAS = *visual analogue scale*; CAM = *Confusion Assessment Method*; LOS = *length of stay*; RCT = *randomized controlled trial*.

## 5. ANESTHETIC TECHNIQUES AND POSTOPERATIVE PAIN MANAGEMENT

### 5.1 The Burden of Postoperative Pain

Despite advances in pharmacology and techniques, moderate to severe postoperative pain continues to be reported by a large share of surgical patients. Poorly controlled acute pain impairs breathing, coughing, and mobilization; increases sympathetic activity, myocardial oxygen demand, and thromboembolic risk; disrupts sleep; and heightens anxiety. The American Pain Society guideline emphasizes that postoperative pain management should begin preoperatively with patient education and planning, and should rely on multimodal regimens tailored to the patient and procedure (Chou et al., 2016).

### 5.2 Multimodal Analgesia

Multimodal analgesia combines drugs and techniques that act at different sites of the pain pathway, producing additive or synergistic analgesia while reducing the dose, and therefore the side effects, of each component. The principal aim is to minimize reliance on opioids while maintaining effective pain control (Wick et al., 2017). A standard foundation for most procedures consists of regular paracetamol and a non-steroidal anti-inflammatory drug or selective COX-2 inhibitor unless contraindicated, supplemented by dexamethasone, regional or local anesthetic techniques, and opioids reserved for breakthrough pain. The concept of procedure-specific analgesia, promoted by international initiatives, recognizes that the optimal regimen for a laparoscopic cholecystectomy differs from that for a total knee arthroplasty or a cesarean delivery (Joshi & Kehlet, 2019).

**Table 3.** Components of a Multimodal Analgesic Strategy

| Component                            | Examples                                                      | Role in Recovery                                         | Key Cautions                                                  |
|--------------------------------------|---------------------------------------------------------------|----------------------------------------------------------|---------------------------------------------------------------|
| <b>Paracetamol</b>                   | Oral or IV, scheduled                                         | Foundation analgesia; opioid sparing                     | Dose adjustment in hepatic impairment and low body weight     |
| <b>NSAIDs / COX-2 inhibitors</b>     | Ibuprofen, ketorolac, celecoxib                               | Reduce inflammatory pain and opioid need                 | Renal impairment, bleeding, GI ulcer, cardiovascular risk     |
| <b>Corticosteroids</b>               | Dexamethasone single dose                                     | Reduces pain, PONV, and prolongs blocks                  | Transient hyperglycemia, relevant in diabetic patients        |
| <b>Local and regional anesthesia</b> | Wound infiltration, nerve and fascial plane blocks, neuraxial | Targeted, high-quality dynamic analgesia                 | LAST, nerve injury, falls from motor block                    |
| <b>NMDA antagonists</b>              | Low-dose ketamine                                             | Reduces opioid tolerance and hyperalgesia                | Psychomimetic effects at higher doses                         |
| <b>Alpha-2 agonists</b>              | Dexmedetomidine, clonidine                                    | Sedative-analgesic and opioid sparing                    | Bradycardia, hypotension, delayed emergence                   |
| <b>IV lidocaine</b>                  | Intraoperative infusion                                       | May improve bowel function and pain in abdominal surgery | Toxicity monitoring; avoid combination with large block doses |
| <b>Opioids (rescue)</b>              | Oral oxycodone, IV morphine, PCA                              | Breakthrough pain control                                | Respiratory depression, PONV, ileus, persistent use           |

*Note.* IV = intravenous; NSAIDs = non-steroidal anti-inflammatory drugs; COX-2 = cyclooxygenase-2; NMDA = N-methyl-D-aspartate; PCA = patient-controlled analgesia.

### 5.3 Regional Anesthesia as an Analgesic Strategy

Regional techniques provide the most effective dynamic analgesia for many procedures, particularly orthopedic, thoracic, and breast surgery. Single-injection blocks typically last 12 to 24 hours, which may be extended by perineural catheters or adjuncts such as dexamethasone. A recognized challenge is rebound pain, a sharp increase in pain intensity as the block resolves, often at night after discharge. Anticipatory prescribing of oral analgesics, patient education, and scheduled multimodal medication before block regression can reduce this problem. Fascial plane blocks offer a safer, simpler alternative to neuraxial techniques in anticoagulated patients, although their efficacy varies by procedure.

### 5.4 Opioid Stewardship and Persistent Opioid Use

Opioids remain indispensable for severe acute pain, yet their perioperative use carries significant risks. Brummett et al. (2017) found that new persistent opioid use occurred in approximately 6% of previously opioid-naïve patients after both minor and major surgery, with rates that did not differ substantially between procedure types, suggesting that the exposure itself, rather than surgical severity, drives risk. Perioperative opioid stewardship includes minimizing intraoperative long-acting opioids where possible, preferring oral over parenteral routes, prescribing the lowest effective dose for the shortest duration at discharge, providing clear tapering and disposal instructions, and identifying high-risk patients such as those with preexisting opioid use, depression, or substance use disorders.

*“Effective pain management is measured not only by lower pain scores, but by how quickly patients can move, breathe, sleep, and return to their lives without long-term opioid dependence.”*

## 5.5 Prevention of Chronic Post-Surgical Pain

Chronic post-surgical pain, defined as pain persisting at least three months after surgery, affects a substantial minority of patients after procedures such as thoracotomy, mastectomy, amputation, and inguinal hernia repair (Kehlet et al., 2006; Macrae, 2008). Risk factors include severe acute postoperative pain, preexisting pain, psychological vulnerability, nerve injury during surgery, and genetic predisposition. A Cochrane review suggested that epidural anesthesia for thoracotomy and paravertebral block for breast cancer surgery may reduce the risk of persistent postoperative pain in some patients, although the certainty of evidence is low to moderate (Weinstein et al., 2018). Early identification and aggressive management of severe acute pain are therefore essential preventive strategies.

## 5.6 Anesthetic Technique and Cancer Recurrence

Laboratory and retrospective studies suggested that regional anesthesia and propofol might reduce cancer recurrence by attenuating the surgical stress response, reducing opioid-mediated immunosuppression, and limiting volatile-agent effects on tumor cells. However, a large international randomized trial of women undergoing breast cancer surgery found no difference in recurrence between regional anesthesia with propofol and general anesthesia with sevoflurane and opioids (Sessler et al., 2019). Although research continues in other cancer types, current evidence does not support choosing an anesthetic technique on the basis of oncological outcome alone.

## 6. CONSIDERATIONS IN SPECIAL POPULATIONS

- ◆ **Elderly patients:** Older patients have reduced physiological reserve, greater sensitivity to anesthetic and opioid drugs, and higher risk of delirium and falls. Anesthetic priorities include careful dose titration, avoidance of delirigenic medications, maintenance of blood pressure, regional analgesia to reduce opioid exposure, and early mobilization with sensory aids such as glasses and hearing aids.
- ◆ **Obstetric patients:** Neuraxial anesthesia is the standard of care for cesarean delivery, allowing the mother to remain awake and reducing airway risks. Intrathecal morphine combined with scheduled paracetamol and NSAIDs forms the analgesic foundation, with TAP or quadratus lumborum blocks for patients unable to receive neuraxial opioids.
- ◆ **Pediatric patients:** Children experience high rates of emergence delirium and PONV. Propofol-based techniques, caudal or peripheral blocks, and weight-based multimodal analgesia with parental involvement improve recovery. Pain assessment must use age-appropriate tools such as FLACC or faces scales.
- ◆ **Patients with obesity and OSA:** Obesity and obstructive sleep apnea increase the risk of opioid-induced respiratory depression. Opioid-sparing multimodal analgesia, regional techniques, head-up positioning, and continuous monitoring are essential. This is particularly relevant in Saudi Arabia, where obesity prevalence is high and bariatric surgery volumes are substantial.
- ◆ **Opioid-tolerant patients:** Patients already taking opioids require continuation of baseline doses, early involvement of acute pain services, generous use of adjuncts such as ketamine, and realistic expectation setting.
- ◆ **Ambulatory surgery patients:** Rapid emergence, minimal PONV, and effective oral analgesia are prerequisites for same-day discharge. TIVA, short-acting agents, regional blocks, and comprehensive discharge instructions support safe outcomes at home.

## 7. THE SAUDI ARABIAN HEALTHCARE CONTEXT

Saudi Arabia is undergoing one of the most ambitious health system transformations in the region. The Health Sector Transformation Program under Vision 2030 aims to improve access, quality, efficiency, and patient experience through a shift toward value-based, integrated care delivered by health clusters. Perioperative services are central to this agenda because surgical care accounts for a significant proportion of hospital costs and patient safety events. Several national institutions shape recovery-oriented anesthesia practice. The Saudi Commission for Health Specialties (SCFHS) oversees postgraduate training programs in anesthesia, including fellowships in regional anesthesia, pain medicine, and pediatric anesthesia, and regulates professional

classification and continuing professional development. CBAHI national standards require hospitals to have structured processes for pain assessment, reassessment, and management, as well as anesthesia and sedation safety standards. The SFDA regulates the importation, prescribing, and dispensing of controlled substances, including opioids, which influences the availability of certain agents and the design of opioid stewardship programs. Digital transformation initiatives, including the national health information exchange and the Nphies platform for insurance claims and clinical data, create opportunities to capture perioperative outcome data at scale. Research centers such as the King Abdullah International Medical Research Center (KAIMRC) support clinical trials and outcome research that can generate locally relevant evidence. Despite these strengths, challenges remain. Practice variation between hospitals and clusters is common, access to ultrasound-guided regional anesthesia and formal acute pain services varies between tertiary centers and peripheral hospitals, and systematic measurement of patient-reported recovery outcomes is not yet routine. Cultural factors also deserve attention: expressions of pain, expectations about opioid use, and family involvement in care decisions differ among patients, and effective communication in Arabic and other languages spoken by patients and staff is essential. The large expatriate component of the anesthesia workforce brings valuable diversity of training but also necessitates standardized local protocols to ensure consistency.

## 8. THE RESTORE FRAMEWORK FOR RECOVERY-ORIENTED ANESTHESIA

Drawing on the evidence reviewed above and the theoretical foundations of Donabedian's model, ERAS, and the biopsychosocial model of pain, this paper proposes the RESTORE framework. The framework is designed to translate evidence into institutional practice by organizing recovery-oriented anesthesia into seven interdependent pillars. Each pillar includes core actions and measurable indicators, allowing hospitals to evaluate progress through structure, process, and outcome metrics.

**Table 4.** The RESTORE Framework: Pillars, Core Actions, and Indicators

| Pillar                                        | Description                                         | Core Actions                                                                                                    | Example Indicators                                    |
|-----------------------------------------------|-----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| <b>R – Risk Stratification</b>                | Identify patient and procedure risks before surgery | Preoperative screening for PONV, OSA, frailty, delirium, chronic pain, and opioid use                           | % of patients with documented risk scores             |
| <b>E – Evidence-Based Technique Selection</b> | Match anesthetic technique to patient and procedure | Use procedure-specific protocols; consider TIVA for high PONV risk; regional techniques where evidence supports | Protocol adherence rate; PONV incidence               |
| <b>S – Stewardship of Opioids</b>             | Minimize unnecessary opioid exposure                | Opioid-sparing adjuncts; oral routes; limited discharge prescriptions; disposal education                       | Mean MME per patient; discharge prescription quantity |
| <b>T – Tailored Multimodal Analgesia</b>      | Individualize analgesic regimens                    | Scheduled non-opioid foundation; adjuncts; anticipatory management of block regression                          | Pain scores on movement at 24 hours                   |
| <b>O – Outcome Measurement</b>                | Capture clinical and patient-reported outcomes      | Routine QoR-15, delirium screening, and follow-up for persistent pain                                           | QoR-15 completion rate; delirium incidence            |
| <b>R – Robust Safety Systems</b>              | Build multiple defenses against harm                | Sedation scoring, capnography for high-risk patients, LAST protocols, standardized handover                     | Naloxone use; respiratory events; block complications |
| <b>E – Education and Engagement</b>           | Empower staff, patients, and families               | Preoperative education in Arabic and English; staff training in regional anesthesia; CPD linked to SCFHS        | Staff trained (%); patient satisfaction               |

*Note. The RESTORE framework is an original conceptual model proposed in this paper and is intended for adaptation and validation in local institutional settings.*

The pillars are sequential in logic but continuous in practice. Risk stratification informs technique selection; technique selection shapes the stewardship and analgesic plans; outcome measurement provides feedback that refines protocols; safety systems protect patients throughout; and education sustains the entire cycle. Mapping the framework to Donabedian's model, structural elements include ultrasound equipment, infusion pumps, acute pain teams, and electronic order sets; process elements include adherence to screening and protocols; and outcome elements include pain, PONV, delirium, length of stay, and patient-reported recovery.

## 9. IMPLEMENTATION CHALLENGES AND RECOMMENDATIONS

Translating evidence into sustained practice change is often more difficult than generating the evidence itself. Implementation science highlights the importance of leadership, local champions, audit and feedback, and adaptation to context. The following table summarizes key challenges in implementing recovery-oriented anesthesia and corresponding strategies for Saudi institutions.

**Table 5.** Implementation Challenges and Recommended Strategies

| Challenge                                      | Recommended Strategy                                                                      | Responsible Stakeholders                        |
|------------------------------------------------|-------------------------------------------------------------------------------------------|-------------------------------------------------|
| <b>Variation in regional anesthesia skills</b> | Structured ultrasound-guided training, simulation, and credentialing pathways             | Anesthesia departments; SCFHS training programs |
| <b>Limited acute pain services</b>             | Establish nurse-led or anesthesia-led acute pain teams with daily rounds                  | Hospital administration; nursing leadership     |
| <b>Lack of outcome data</b>                    | Integrate QoR-15, pain, and PONV fields into electronic health records and dashboards     | Health informatics; quality departments         |
| <b>Opioid over-prescribing at discharge</b>    | Standardized procedure-specific discharge prescribing guidelines                          | Surgeons; pharmacists; anesthesiologists        |
| <b>Inconsistent protocol adherence</b>         | ERAS coordinators, audit and feedback cycles, and CBAHI-aligned indicators                | Quality and patient safety units                |
| <b>Patient expectations and communication</b>  | Culturally adapted education materials and family engagement                              | Nursing; health education teams                 |
| <b>Drug and equipment availability</b>         | Formulary planning with SFDA regulations and procurement of pumps and ultrasound machines | Pharmacy; supply chain; clusters                |

Based on the evidence and the Saudi context, the following recommendations are proposed for health clusters, hospitals, and anesthesia departments:

- ◆ Adopt procedure-specific, evidence-based anesthesia and analgesia protocols embedded within ERAS pathways for high-volume surgeries such as arthroplasty, cesarean delivery, bariatric, colorectal, and laparoscopic procedures.
- ◆ Implement routine PONV risk assessment and risk-adapted prophylaxis, with propofol TIVA considered for high-risk patients.
- ◆ Expand ultrasound-guided regional anesthesia capabilities across clusters, supported by SCFHS-accredited training and credentialing.

- ◆ Establish formal acute pain services and opioid stewardship programs, with pharmacist participation and standardized discharge prescribing.
- ◆ Measure patient-reported recovery routinely using validated tools such as the QoR-15, translated and validated for Arabic-speaking populations.
- ◆ Develop national perioperative outcome registries linked to digital health platforms to support benchmarking, research, and value-based purchasing.
- ◆ Invest in locally conducted clinical research through centers such as KAIMRC to generate context-specific evidence on anesthetic techniques and recovery.

## 10. FUTURE DIRECTIONS

Several emerging areas promise to refine the relationship between anesthetic technique and recovery. First, precision anesthesia, informed by pharmacogenomics and individual pain phenotyping, may allow clinicians to predict which patients will benefit most from specific techniques or analgesics. Second, processed EEG and nociception monitoring technologies may help individualize anesthetic depth and intraoperative analgesia, potentially reducing delirium and opioid exposure, although robust outcome evidence is still evolving. Third, long-acting local anesthetic formulations and continuous catheter techniques may extend the benefits of regional anesthesia into the post-discharge period. Fourth, artificial intelligence and predictive analytics applied to electronic health record data could identify patients at high risk of severe pain, PONV, or persistent opioid use, enabling proactive intervention. Fifth, digital follow-up tools such as mobile applications and remote monitoring may support patients after ambulatory surgery and capture late recovery outcomes. Finally, sustainability considerations, including reduction of desflurane and nitrous oxide use, are likely to influence technique selection alongside clinical outcomes. Research priorities for Saudi Arabia include validation of patient-reported recovery measures in Arabic, multicenter studies of regional anesthesia outcomes across health clusters, evaluation of opioid prescribing patterns after surgery, and cost-effectiveness analyses of TIVA, regional techniques, and ERAS programs within the national health financing model.

## 11. CONCLUSION

The anesthetic technique is a powerful but frequently underestimated determinant of postoperative recovery and pain. Current evidence shows that propofol-based TIVA reduces PONV and may improve early recovery quality; that regional and neuraxial techniques provide superior dynamic analgesia and reduce opioid requirements; and that multimodal, procedure-specific analgesia within ERAS pathways yields the most consistent benefits. At the same time, large randomized trials have tempered earlier enthusiasm, showing that regional anesthesia does not clearly reduce delirium, mortality, or cancer recurrence, and that opioid-free anesthesia is not automatically superior to balanced opioid-sparing approaches. The lesson for clinicians and health system leaders is that no single technique is universally best. Optimal recovery results from individualized technique selection, anticipatory and multimodal analgesia, responsible opioid stewardship, robust safety systems, and continuous measurement of outcomes that matter to patients. The RESTORE framework proposed in this paper provides a structured pathway to operationalize these principles. For Saudi Arabia, aligning recovery-oriented anesthesia with the goals of Vision 2030, supported by SCFHS training, CBAHI standards, SFDA regulation, and national digital health infrastructure, offers a significant opportunity to improve surgical outcomes, patient experience, and the value of perioperative care.

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