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Future Of Analgesia Beyond Catheters

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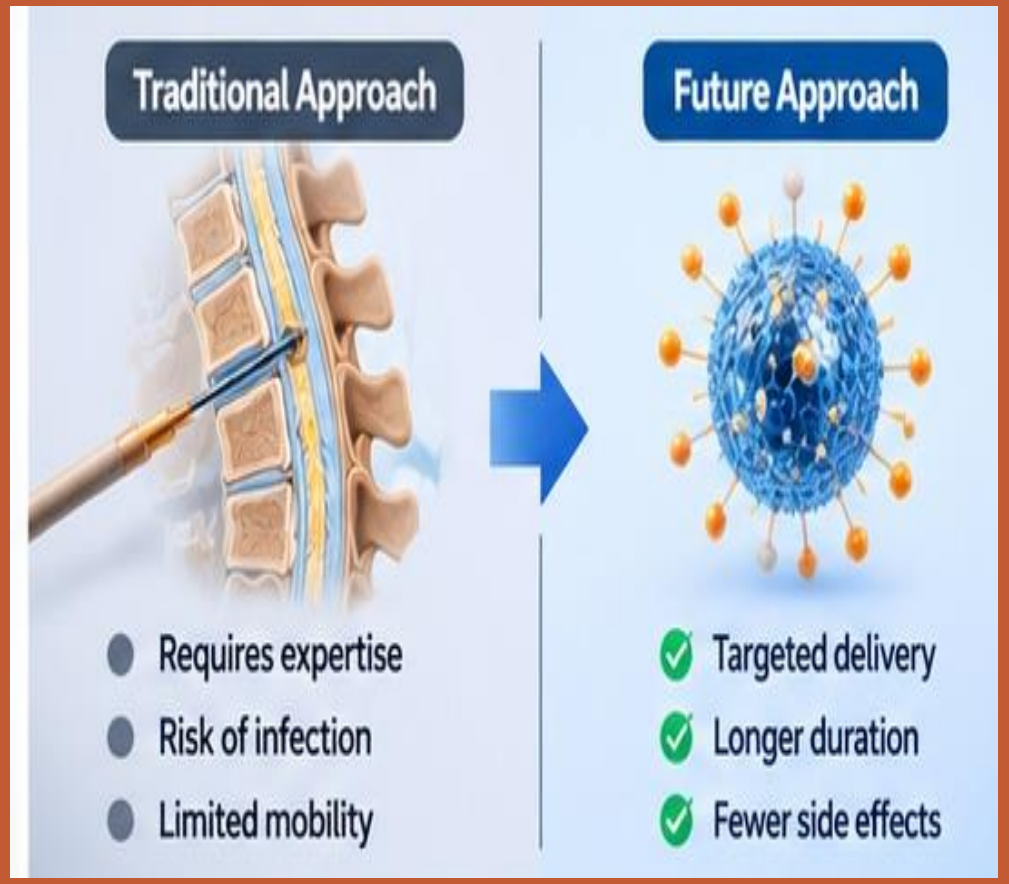
Why Think Beyond Catheters?

- Regional and epidural catheters can provide effective analgesia in selected settings, but require expertise, monitoring, and device care
- Potential limitations include infection, dislodgement, occlusion, leakage, mobility constraints, and challenges outside the hospital
- The goal is not simply to deliver a drug: target selection, timing, functional recovery, and minimizing harm also matter
- The future is likely to combine mechanism-based medicines, smarter delivery, and multimodal care



Roadmap

- Revisit pain mechanisms and limitations of current treatments
- Explore non-opioid medicines and selective targets in pain pathways
- Review emerging delivery platforms: nanocarriers, hydrogels, depots, and implants
- Consider smart technologies, bioelectronics, and artificial intelligence
- Translate innovation into practice: evidence, safety, access, and patient-centered outcomes

A Roadmap Toward 2030

A plausible direction of travel—not a prediction of guaranteed adoption



NOW

Evidence-based multimodal care
Selective new non-opioids

NEAR TERM

Better pathway selection
Long-acting formulations

MID TERM

More mechanism-specific drugs
Digital outcome monitoring

TOWARD 2030

Validated decision support
More individualized pathways

Adoption will depend on comparative effectiveness, cost, regulation and real-world outcomes

Pain Is Not One Entity

- Nociceptive pain: associated with tissue injury or inflammation; selected patients may benefit from anti-inflammatory treatment
- Neuropathic pain: caused by a lesion or disease of the somatosensory system; treatment may target abnormal neuronal excitability
- Nociplastic pain: altered nociception without sufficient evidence that tissue damage or a somatosensory lesion fully explains the pain
- Clinical implication: no single drug or delivery route is suitable for every pain phenotype



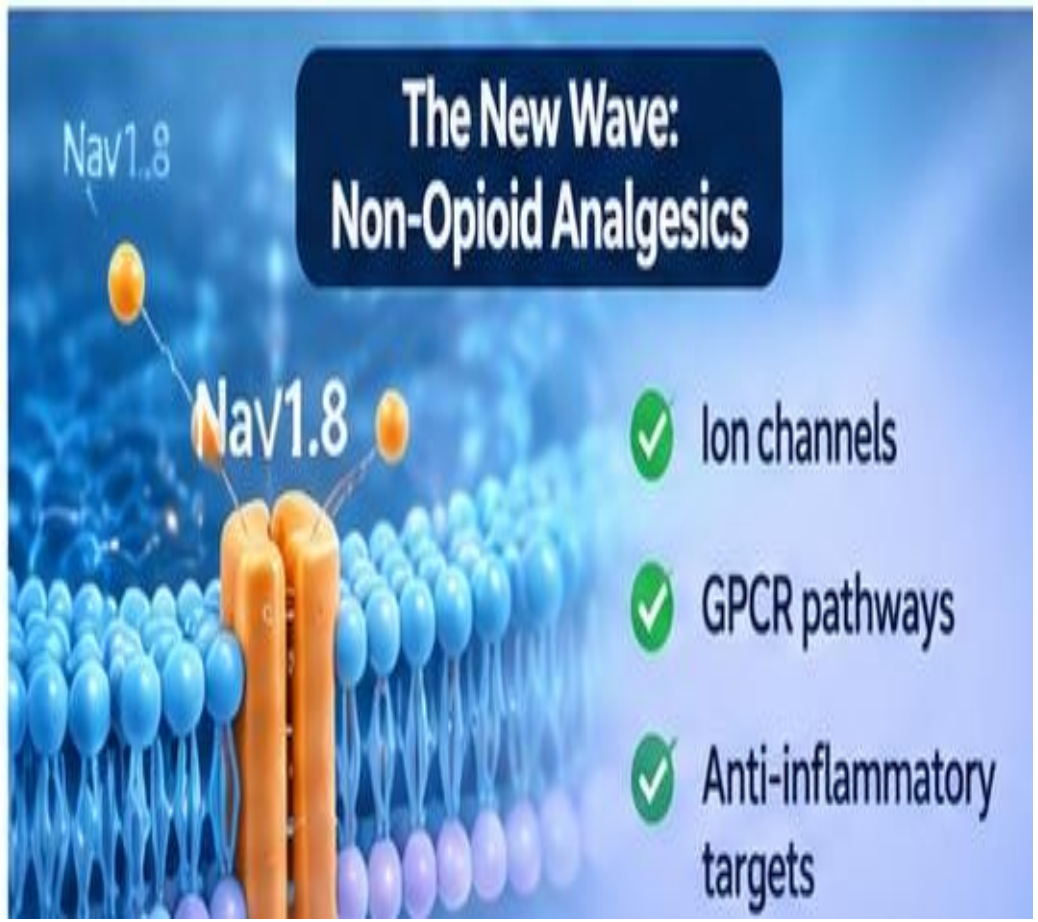
Limitations of Current Approaches

- ***Opioids*** can be effective in selected settings but carry risks including dependence, tolerance, adverse effects, and respiratory depression.
- ***NSAIDs*** and acetaminophen help in selected pain states, but patient-specific gastrointestinal, renal, hepatic, or cardiovascular risks matter.
- ***Adjuvant medicines*** for neuropathic pain have variable efficacy and may cause dizziness or sedation.
- ***Catheters and pumps*** enable regional or continuous delivery but add device-related risks and care requirements.
- Unmet need: more precise, safer, and practical options.

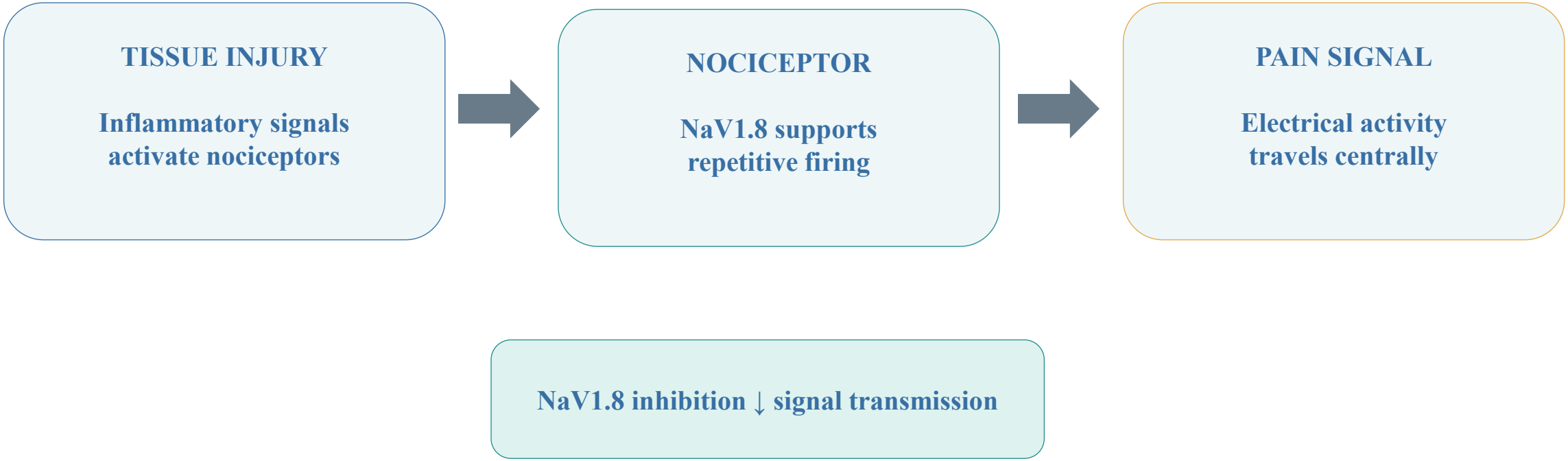


The New Wave: Non-Opioid Analgesics

- The aim is to reduce reliance on μ-opioid receptor activation by targeting other pain pathways
- Research targets include ion channels, G-protein-coupled receptors, and inflammatory pathways
- Selective inhibition of peripheral sodium channels may reduce pain-signal transmission before signals reach the central nervous system
- These approaches are not interchangeable across all pain conditions; indication-specific clinical evidence is essential



NaV1.8: Interrupting Peripheral Pain Signaling



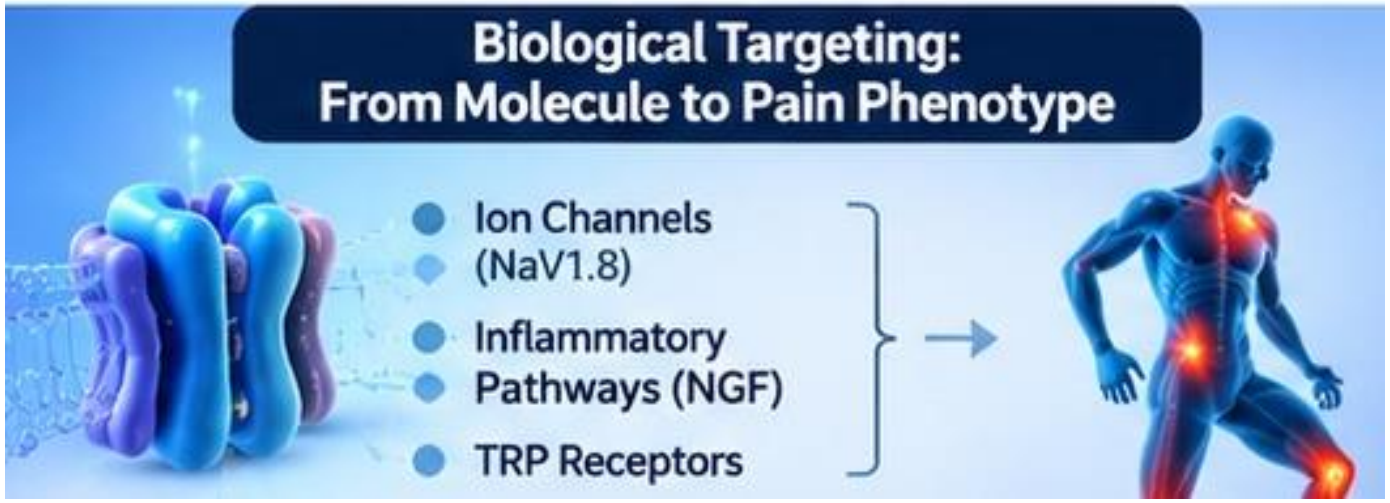
Mechanism-based does not mean side-effect-free; use within the approved indication and prescribing information

Clinical Milestone: Suzetrigine

- In January 2025, the FDA approved Journavx (suzetrigine) for moderate-to-severe acute pain in adults
- Mechanism: selective inhibition of the voltage-gated sodium channel NaV1.8 in peripheral pain-signaling pathways
- Significance : an example of a non-opioid analgesic with a defined molecular target not merely a new delivery route
- Important limitation: approval for acute pain does not establish effectiveness for every chronic or neuropathic pain condition



Biological Targets: From Molecule to Pain Phenotype



- ***Ion channels***: NaV1.8 and other pathways under investigation that influence neuronal excitability
- ***Inflammatory pathways and NGF***(Nerve Growth Factor= neurotrophin protein): potential roles in selected conditions, requiring careful benefit–risk assessment
- ***TRP***(a family of ion channels located in cell membranes) and other sensory receptors: targets involved in responses to thermal and chemical stimuli
- Future direction: treatment selection based on clinical phenotype, biomarkers when validated, and prior response—not just the label “pain”

Beyond Catheters: Emerging Delivery Platforms



- ***Long-acting formulations*** and injectable depots may extend drug release over time
- ***Hydrogels are biocompatible networks*** being studied for drug retention and controlled local release
- ***Micro- and nanocarriers*** may alter stability, distribution, and targeting; many applications remain investigational
- ***Drug-delivery implants*** may suit selected indications but must justify invasiveness and device-related risks
- Key principle: local delivery and controlled release matter only if they improve meaningful clinical outcomes

Hydrogels and Stimuli-Responsive Release



- Hydrogels can retain a drug within a polymer network and modulate its release
- Responsive systems are being explored for triggers such as pH, temperature, enzymes, or other local cues
- Theoretical advantages include longer local residence and lower systemic exposure
- Challenges include biocompatibility, mechanical durability, reproducible manufacturing, and human safety data
- Evidence maturity varies; promising platforms should not be confused with established standard care

Nanomedicine and Spatiotemporal Targeting

Lipid and polymer-based carriers can change drug distribution and release characteristics

- Active or passive targeting and local depots are among the strategies being investigated
- Timed or stimulus-responsive release could, in principle, better match treatment to patient needs
- Translation barriers include unintended accumulation, toxicity, manufacturing complexity, scalability, and cost
- Many platforms remain preclinical or in early clinical development



Wearables and Bioelectronics

- Wearables can capture movement, sleep, and physiological signals; these are not direct substitutes for a patient's pain report
- Neural interfaces and targeted stimulation may complement medication in selected patients
- If validated, closed-loop systems could link monitoring with more adaptive interventions
- Virtual reality and multisensory approaches are also being studied as non-pharmacological adjuncts
- Challenges include privacy, algorithmic error, patient acceptance, and proof of meaningful benefit



AI and Personalized Pain Care



- AI may help discover drug targets and prioritize compounds during research
- Combining clinical, functional, and patient-reported data may support decisions—but should not replace clinician judgment
- Predictive models may eventually help guide treatment selection and follow-up
- Clinical deployment requires external validation, transparency, bias control, and data protection
- Principle: AI should support care, not reduce the patient's pain experience to a single score

Multimodal Care—Not a Single Magic Bullet

- Carefully selected medicines with complementary mechanisms may improve coverage of pain pathways
- When appropriate, regional techniques, rehabilitation, sleep support, psychological care, and patient education can work together
- Define goals clearly: pain reduction, better function and sleep, fewer adverse effects, and reduced rescue medication where relevant
- Plans should reflect acute versus chronic pain, comorbidities, and patient preferences

From Innovation to Practice: What Evidence Is Needed?

- Efficacy: magnitude of benefit and clinical importance, not statistical significance alone
- Safety: short- and long-term adverse effects, interactions, and unintended consequences
- Fair comparisons: appropriate standard care, placebo, or reference treatment for the research question
- Patient-centered outcomes: function, quality of life, sleep, return to activity, and opioid use when relevant
- Implementation: cost, access, manufacturing consistency, team training, and equity

Catheter-Based vs. Emerging Approaches

DIMENSION	CATHETER-BASED	EMERGING OPTIONS
Delivery	Continuous infusion	Single-shot / depot / oral targeted therapy
Maintenance	Pump, line and follow-up	Potentially simpler after administration
Flexibility	Infusion can be adjusted	Often less adjustable once administered
Best fit	Selected procedures and prolonged regional analgesia	Selected pathways where duration and simplicity align
Key risk	Device-related and local-anesthetic risks	Duration predictability, systemic safety and evidence gaps

A new direction for perioperative and acute pain care

1

DURATION

Can analgesia last through the high-pain window?

2

TARGETING

Can we act at the relevant pathway or tissue?

3

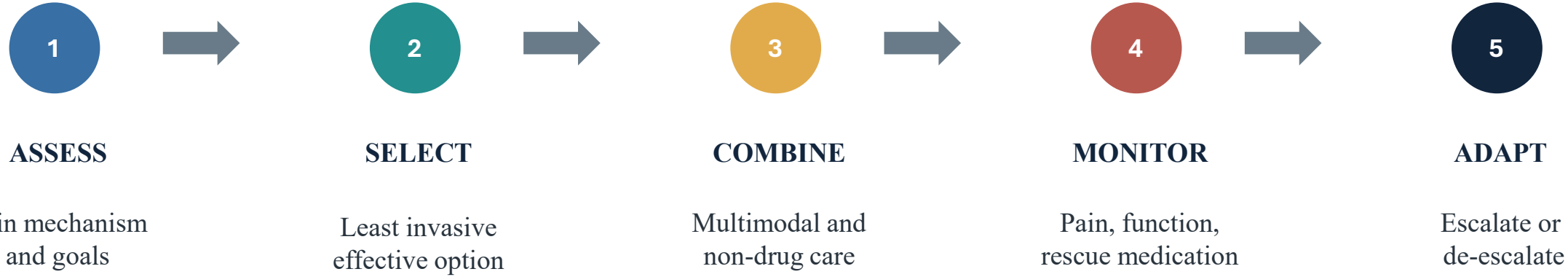
SAFETY and PERSONALIZATION

Can we reduce avoidable systemic exposure?

Can therapy fit the patient and pain phenotype?

A Patient-Centered Future Pathway

From pain phenotype to measured recovery



The outcome loop: pain relief + function + safety + patient experience

The Next 5–10 Years

- Near term: wider evaluation and appropriate use of evidence-supported non-opioid options
- Medium term: more long-acting formulations and precise local systems, if clinical superiority is demonstrated
- Long term: integration of validated biomarkers, digital tools, and personalized treatment strategies
- The likely direction is not complete replacement of catheters, but better matching of each tool to the patient and setting
- Success should be measured by durable relief, better function, and less harm

Key Take-Home Messages

- The future of pain management extends beyond choosing between a catheter and a pill
- Mechanism-based non-opioid medicines are opening new options; suzetrigine is a clinical example
- Hydrogels, nanomedicines, injectable depots, and smart systems are promising, but differ greatly in maturity
- Personalized and multimodal care may improve treatment selection and outcomes
- The central question remains: which intervention for which patient, with what measurable benefit and risk?

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Thank You for Your Attention

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