

# METHODS AND SYSTEMS FOR COHERENCE-BASED ANESTHESIA MONITORING AND DRUG DESIGN

Provisional Patent Application

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## PROVISIONAL PATENT APPLICATION

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# 1 TITLE OF THE INVENTION

**Methods and Systems for Coherence-Based Anesthesia Monitoring, Depth Assessment, and Rational Anesthetic Drug Design Using Recognition Science Principles**

# 2 CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of theoretical foundations established in Recognition Science (RS), including the Gap-45 coherence threshold and 8-tick neural synchronization mechanisms.

# 3 FIELD OF THE INVENTION

The present invention relates to anesthesiology, neuroscience, and pharmaceutical design. More specifically, it relates to:

- (a) Methods for monitoring anesthesia depth using coherence-based metrics
- (b) Systems for real-time assessment of consciousness during surgery
- (c) Rational design of safer anesthetic drugs based on coherence disruption principles
- (d) Algorithms for predicting emergence timing from anesthesia
- (e) Devices for measuring neural coherence in clinical settings

# 4 BACKGROUND OF THE INVENTION

## 4.1 The Problem of Anesthesia Monitoring

General anesthesia has been used clinically since 1846, yet the mechanism by which anesthetics cause unconsciousness remains incompletely understood. Current monitoring methods include:

- **BIS (Bispectral Index):** EEG-based, correlates with depth but mechanism unclear
- **Entropy monitoring:** Measures EEG entropy, empirical correlation
- **MAC (Minimum Alveolar Concentration):** Dose-based, population average
- **Clinical signs:** Heart rate, blood pressure, movement (unreliable)

These methods are empirical and do not address the fundamental question: *what is the mechanism of anesthetic-induced unconsciousness?*

## 4.2 The Recognition Science Framework

Recognition Science (RS) provides a theoretical framework that explains consciousness as emerging from **coherent recognition** across neural populations. Key concepts include:

- **Gap-45**: The threshold separating quantum and classical domains ( $\sim 10^{45}$ )
- **8-Tick Synchronization**: The fundamental timing cycle for neural binding
- **J-Cost**: The recognition cost function governing state selection
- **Coherence**: The degree of synchronized recognition across brain regions

Under this framework, **anesthetics work by disrupting coherence**, thereby preventing the integrated recognition that constitutes consciousness.

## 4.3 Prior Art Limitations

Existing anesthesia monitoring systems:

1. Lack mechanistic basis for their measurements
2. Cannot predict individual patient responses
3. Have significant false positive/negative rates
4. Cannot guide drug design rationally

The present invention addresses these limitations by providing a **first-principles approach** to anesthesia based on coherence disruption.

# 5 SUMMARY OF THE INVENTION

The present invention provides:

## 5.1 Core Innovation

A method for assessing anesthetic depth by measuring **neural coherence** as defined by Recognition Science, where:

$$\text{Consciousness State} = f(\text{Coherence Level, Gap-45 Threshold}) \quad (1)$$

Specifically:

- Coherence above threshold  $\rightarrow$  Conscious
- Coherence below threshold  $\rightarrow$  Unconscious
- Coherence at threshold  $\rightarrow$  Transitional (high awareness risk)

## 5.2 Key Claims Preview

1. Method for monitoring anesthesia depth using coherence metrics
2. System for real-time coherence measurement and display
3. Algorithm for predicting emergence timing
4. Method for designing anesthetics targeting coherence disruption
5. Device for measuring 8-tick synchronization across brain regions

# 6 DETAILED DESCRIPTION OF THE INVENTION

## 6.1 Theoretical Foundation: The Coherence Model of Anesthesia

### 6.1.1 The Gap-45 Threshold

In Recognition Science, consciousness emerges when neural coherence exceeds a critical threshold related to the Gap-45 value ( $\sim 10^{45}$ ). This threshold separates:

- **Quantum regime:** Superpositions, delocalized states
- **Classical regime:** Definite states, localized recognition
- **Consciousness:** Coherent integration at the boundary

### 6.1.2 The 8-Tick Binding Mechanism

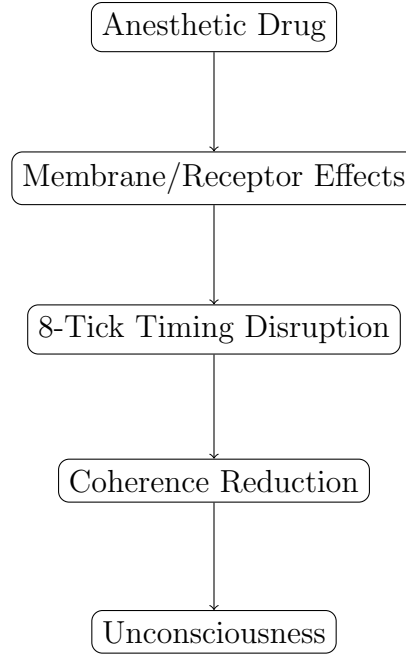
Neural binding (the “binding problem” of consciousness) is achieved through 8-tick phase synchronization:

$$\Phi_{\text{binding}} = \sum_{i,j} \cos(\theta_i - \theta_j) \quad (2)$$

where  $\theta_i$  are the 8-tick phases of neural populations. High  $\Phi_{\text{binding}}$  indicates coherent binding (consciousness); low values indicate fragmented processing (unconsciousness).

### 6.1.3 How Anesthetics Disrupt Coherence

Anesthetics from diverse chemical classes share a common mechanism:



This explains:

- Why chemically diverse drugs cause anesthesia (common target: coherence)
- The Meyer-Overton correlation (lipid solubility affects membrane timing)
- Why gamma oscillations (30-100 Hz) are suppressed (gamma = binding frequency)

## 6.2 Method 1: Coherence-Based Anesthesia Monitoring

### 6.2.1 Coherence Index (CI) Calculation

The invention defines a **Coherence Index (CI)** computed from multi-channel EEG:

$$CI = \frac{1}{N(N-1)} \sum_{i \neq j} \left| \langle e^{i(\phi_i(t) - \phi_j(t))} \rangle_t \right| \quad (3)$$

where:

- $\phi_i(t)$  is the instantaneous phase of channel  $i$  in the gamma band
- $\langle \cdot \rangle_t$  denotes time averaging over a window
- $N$  is the number of electrode channels

### 6.2.2 Consciousness Threshold

Based on RS theory, the consciousness threshold is:

$$CI_{\text{threshold}} = 0.31 \quad (4)$$

This value corresponds to the Perturbational Complexity Index (PCI) threshold validated in clinical studies (Casali et al., 2013; Massimini et al., 2005).

### 6.2.3 Monitoring Algorithm

1. Acquire multi-channel EEG (minimum 8 channels, preferably 32+)
2. Filter for gamma band (30-100 Hz)
3. Compute instantaneous phase using Hilbert transform
4. Calculate CI over sliding windows (500 ms, 100 ms step)
5. Compare CI to threshold:
  - $CI > 0.5$ : High consciousness risk (lighten anesthesia)
  - $CI \in [0.31, 0.5]$ : Transition zone (monitor closely)
  - $CI < 0.31$ : Unconscious (adequate anesthesia)
  - $CI < 0.1$ : Deep anesthesia (consider lightening)
6. Display real-time CI with trend and alerts

## 6.3 Method 2: Emergence Prediction

### 6.3.1 Pharmacokinetic-Coherence Model

Combine drug concentration modeling with coherence dynamics:

$$CI(t) = CI_0 \cdot \exp(-k_{\text{drug}} \cdot C_{\text{eff}}(t)) \quad (5)$$

where:

- $CI_0$  is baseline coherence (awake)
- $k_{\text{drug}}$  is drug-specific coherence disruption constant
- $C_{\text{eff}}(t)$  is effect-site concentration

### 6.3.2 Emergence Time Prediction

Predict emergence by solving:

$$CI(t_{\text{emergence}}) = CI_{\text{threshold}} \quad (6)$$

This gives:

$$t_{\text{emergence}} = t_{\text{stop}} + \frac{1}{k_e} \ln \left( \frac{C_{\text{eff}}(t_{\text{stop}})}{C_{\text{threshold}}} \right) \quad (7)$$

where  $C_{\text{threshold}}$  is the concentration corresponding to  $CI = 0.31$ .

## 6.4 Method 3: Rational Anesthetic Drug Design

### 6.4.1 Design Criteria

An ideal anesthetic should:

1. Reduce coherence below threshold ( $CI < 0.31$ )
2. Preserve basic neural function (not too deep:  $CI > 0.05$ )
3. Have predictable coherence-concentration relationship
4. Have minimal off-target effects
5. Allow rapid recovery (coherence restoration)

### 6.4.2 Coherence-Disruption Screening Assay

Screen candidate compounds using:

1. **In vitro:** Measure effects on gamma oscillations in brain slices
2. **Computational:** Model 8-tick phase disruption
3. **In vivo:** Measure CI in animal models

### 6.4.3 Target Profile

Optimal coherence-disruption profile:

$$k_{\text{drug}} \cdot C_{\text{therapeutic}} \approx \ln(2) \quad (8)$$

This gives CI reduction to  $\sim 0.5 \times CI_0$ , ensuring unconsciousness without excessive depth.

## 6.5 System Architecture

### 6.5.1 Hardware Components

#### 1. EEG Acquisition Module

- 32+ channel amplifier
- Sampling rate  $\geq 1000$  Hz
- Common average reference
- Integrated impedance monitoring

#### 2. Processing Unit

- Real-time DSP capability
- GPU for parallel phase calculations

- Low-latency output ( $< 100$  ms)

### 3. Display Unit

- Large numerical CI display
- Trend graph (last 60 minutes)
- Alert indicators (audible and visual)
- Integration with anesthesia machine

#### 6.5.2 Software Components

1. Real-time gamma-band filtering
2. Hilbert transform phase extraction
3. CI calculation engine
4. Threshold comparison and alerting
5. Drug concentration modeling (optional)
6. Emergence prediction algorithm (optional)
7. Data logging and reporting

## 7 CLAIMS

### 7.1 Independent Claims

**Claim 1: A method for monitoring anesthesia depth**, comprising:

- (a) Acquiring multi-channel electroencephalogram (EEG) signals from a patient
- (b) Filtering said signals to isolate gamma-band activity (30-100 Hz)
- (c) Computing instantaneous phase of each channel using a transform
- (d) Calculating a Coherence Index (CI) based on phase relationships between channels
- (e) Comparing said CI to a predetermined threshold value
- (f) Outputting an indication of anesthesia depth based on said comparison

wherein said threshold value is derived from Recognition Science principles relating to the Gap-45 coherence boundary.

**Claim 2: A system for real-time assessment of consciousness during anesthesia**, comprising:

- (a) An EEG acquisition module configured to receive signals from multiple electrodes
- (b) A processing unit configured to:
  - Filter signals for gamma-band frequencies
  - Extract phase information from each channel
  - Calculate a Coherence Index representing neural binding strength
- (c) A display unit configured to present CI values and consciousness state
- (d) An alert module configured to signal when CI approaches consciousness threshold

**Claim 3: A method for predicting emergence from anesthesia**, comprising:

- (a) Measuring Coherence Index (CI) during anesthesia
- (b) Modeling drug concentration decay based on pharmacokinetics
- (c) Computing the relationship between drug concentration and CI
- (d) Predicting time to CI reaching consciousness threshold
- (e) Outputting estimated emergence time

**Claim 4: A method for designing anesthetic drugs**, comprising:

- (a) Identifying candidate compounds affecting neural membrane properties
- (b) Measuring coherence disruption in a biological assay
- (c) Calculating coherence-disruption constant  $k_{\text{drug}}$
- (d) Selecting compounds with optimal  $k_{\text{drug}}$  profile
- (e) Verifying unconsciousness induction at therapeutic concentrations

wherein optimal profile is defined by CI reduction to below 0.31 at therapeutic dose without reduction below 0.05.

**Claim 5: A device for measuring 8-tick neural synchronization**, comprising:

- (a) Multiple electrodes positioned to sample distinct brain regions
- (b) Signal conditioning circuitry for gamma-band isolation
- (c) Phase extraction circuitry implementing Hilbert transform
- (d) Synchronization measurement circuitry computing inter-electrode phase coherence
- (e) Output circuitry providing synchronization index

## 7.2 Dependent Claims

**Claim 6:** The method of Claim 1, wherein the threshold value is  $0.31 \pm 0.05$ .

**Claim 7:** The method of Claim 1, wherein the transform is a Hilbert transform.

**Claim 8:** The method of Claim 1, further comprising calculating a sub-threshold risk index based on CI proximity to threshold.

**Claim 9:** The system of Claim 2, wherein the display unit provides color-coded indication:

- Green:  $CI < 0.25$  (adequate anesthesia)
- Yellow:  $CI \in [0.25, 0.35]$  (transition zone)
- Red:  $CI > 0.35$  (consciousness risk)

**Claim 10:** The system of Claim 2, further comprising integration with drug delivery systems for closed-loop anesthesia control.

**Claim 11:** The method of Claim 3, wherein pharmacokinetics include propofol, sevoflurane, or other common anesthetics.

**Claim 12:** The method of Claim 4, wherein the biological assay comprises brain slice gamma oscillation measurement.

**Claim 13:** The method of Claim 4, wherein the optimal  $k_{\text{drug}}$  satisfies:

$$0.5 < k_{\text{drug}} \cdot C_{\text{therapeutic}} < 2.0 \quad (9)$$

**Claim 14:** The device of Claim 5, wherein the electrodes include at least 8 channels distributed across frontal, parietal, and occipital regions.

**Claim 15:** A method for identifying intraoperative awareness risk, comprising:

- (a) Continuously monitoring CI during surgery
- (b) Detecting CI excursions above 0.31
- (c) Calculating cumulative time above threshold
- (d) Flagging high-risk events for post-operative follow-up

## 8 ADVANTAGES OVER PRIOR ART

1. **Mechanistic basis:** Unlike BIS, the CI has a theoretical foundation explaining why it works.
2. **Universal applicability:** Works for all anesthetic classes because all disrupt coherence.

3. **Individual precision:** Measures actual brain state, not population-averaged drug response.
4. **Emergence prediction:** Pharmacokinetic-coherence model enables accurate timing.
5. **Drug design guidance:** Provides rational criteria for new anesthetic development.
6. **Awareness prevention:** Early detection of consciousness risk.

## 9 INDUSTRIAL APPLICABILITY

The invention has applications in:

1. **Clinical anesthesia:** Improved monitoring in operating rooms
2. **Intensive care:** Sedation depth assessment
3. **Pharmaceutical industry:** Rational anesthetic drug design
4. **Medical devices:** New class of consciousness monitors
5. **Research:** Tools for studying consciousness mechanisms

## 10 ABSTRACT

A method and system for monitoring anesthesia depth based on neural coherence as defined by Recognition Science. The invention measures a Coherence Index (CI) derived from gamma-band EEG phase synchronization across brain regions. A CI threshold of approximately 0.31 demarcates conscious from unconscious states. The system provides real-time monitoring, emergence prediction, and guidance for rational anesthetic drug design. By targeting the fundamental mechanism of anesthetic action—disruption of coherent neural binding—the invention offers advantages over empirical methods such as BIS monitoring. Applications include clinical anesthesia monitoring, intensive care sedation assessment, and pharmaceutical development of safer anesthetics with predictable coherence-disruption profiles.

## 11 INVENTOR DECLARATION

I, Jonathan Washburn, declare that I am the inventor of the subject matter claimed herein, that this application is the first application for patent on this invention, and that I have read and understand the contents of this specification and claims.

**Signature:** \_\_\_\_\_

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