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Auditory modulation of consciousness during awake craniotomy: Neurophysiological perspectives on meaningful auditory stimulation and the potential role of Quranic Recitation

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Abstract
Awake craniotomy requires patients to remain partially conscious and cooperative while undergoing intracranial surgery, a state in which the auditory channel remains one of the few reliable routes for communication, reassurance, and emotional regulation. Evidence from auditory evoked potential studies, event-related potential research, and investigations in disorders of consciousness indicates that auditory processing persists, at least at a subcortical and often at a cortical level, across a wide range of arousal states, including sedation and general anesthesia. This persistence carries both risk, in the form of implicit distressing memories, and opportunity, in the form of therapeutic auditory input that can modulate autonomic tone, cortical arousal, and subjective experience. This review synthesizes neurophysiological literature on auditory processing under altered consciousness, the psychological burden associated with awake craniotomy, and the growing body of clinical evidence on music- and voice-based interventions in the perioperative setting. It then examines Quranic recitation as a culturally and spiritually salient auditory stimulus, drawing on electroencephalographic, autonomic, and endocrine studies that report increased alpha-band activity, reduced cortisol and adrenocorticotropic hormone levels, and lower self-reported anxiety among Muslim listeners across multiple clinical contexts. A conceptual neurophysiological model is proposed to explain how a semantically and emotionally meaningful auditory stimulus such as Quranic recitation could, in principle, be integrated into the auditory environment of awake craniotomy to support autonomic stability, reduce psychological distress, and preserve the cooperative state required for intraoperative brain mapping, while respecting the technical constraints of language and motor testing. Gaps in direct evidence, methodological limitations of the existing literature, and priorities for future controlled research are discussed.

Keywords: Awake craniotomy, consciousness, auditory evoked potential, Quranic recitation, neurophysiology, intraoperative anxiety, auditory pathway

Introduction
Awake craniotomy is a neurosurgical technique in which patients are kept conscious, or are deliberately reawakened, during resection of brain tumors or epileptogenic tissue located within or adjacent to eloquent cortex. By allowing direct electrical stimulation mapping and real-time behavioral testing of language, motor, and other higher cortical functions, the technique enables surgeons to maximize the extent of resection while minimizing the risk of permanent neurological deficit (McBenedict *et al*., 2024; Meng *et al*., 2017) [18, 26]. Since Bartholow's earliest cortical stimulation experiments and Penfield's systematic development of intraoperative mapping, awake surgery has evolved into a standard of care for gliomas and other lesions situated near language and sensorimotor cortex, and is increasingly extended to lesions in the non-dominant hemisphere as well (McBenedict *et al*., 2024) [18].

Unlike most surgical procedures, awake craniotomy requires the patient to transition between states of sedation, near-full wakefulness, and cooperative task performance within a single operative course. This is most commonly achieved through either the asleep-awake-asleep (AAA) technique, in which general anesthesia is induced and then lightened for the mapping phase, or monitored anesthesia care (MAC), in which light-to-moderate sedation is titrated throughout the procedure with regional scalp block providing analgesia (Natalini *et al*., 2022; Sato & Nishiwaki, 2021) [30, 37]. In both approaches, the patient is never rendered fully unconscious for the entire operation, and during the critical awake phase the patient must reliably perceive, interpret, and respond to auditory instructions from the surgical team while lying immobilized, often for several hours, under bright lights and unfamiliar mechanical sounds (Milian *et al*., 2014) [27].

This unusual physiological and psychological context places the auditory system in a uniquely important position. Vision is frequently obstructed by surgical drapes and head fixation, tactile sensation from the scalp is blocked by regional anesthesia, and the patient's own movement is restricted; audition therefore remains one of the few sensory channels through which the surgical team can communicate, reassure, and orient the patient, and through which the patient can, in turn, signal distress (Milian *et al*., 2014; Sandhu & Dash, 2009) [27, 36]. At the same time, a substantial body of neurophysiological evidence indicates that auditory processing is remarkably resistant to suppression by sedative and anesthetic agents relative to other sensory modalities, with subcortical and even cortical auditory evoked responses detectable well into deeper planes of anesthesia (Ypparila *et al*., 2002; Laureys *et al*., 2000; Mou *et al*., 2015) [23, 28, 40]. This combination of clinical necessity and neurophysiological persistence raises an important question that has received comparatively little systematic attention: can the auditory environment of awake craniotomy be deliberately shaped, using meaningful rather than incidental sound, to support the patient's psychological state and physiological stability without compromising the accuracy of intraoperative language and motor testing?

Intraoperative anxiety and, in a subset of patients, frank panic attacks remain among the most common adverse psychological events during awake craniotomy, occurring in up to 10-16% of patients in some series and constituting one of the leading causes of failed intraoperative mapping (Milian *et al*., 2014) [27]. Because anxiety is known to amplify pain perception and to interfere with the sustained attention required for language and motor tasks, there is a strong clinical rationale for non-pharmacological adjuncts that can be layered onto standard anesthetic technique without adding sedative burden (Milian *et al*., 2014; Sandhu & Dash, 2009) [27, 36]. Music-based interventions have accumulated a substantial evidence base for reducing perioperative anxiety and pain across numerous surgical specialties (Kühlmann *et al*., 2018), and there is growing interest in whether auditory stimuli that carry deeper personal, cultural, or spiritual meaning for the listener produce stronger or more durable physiological effects than generic music (Che Wan Mohd Rozali *et al*., 2022) [13].

For the roughly two billion Muslims worldwide, and for patients treated within Islamic health systems such as Indonesia's, recitation of the Qur'an occupies a distinctive position as an auditory stimulus that is simultaneously linguistic, rhythmic, emotionally resonant, and spiritually meaningful. A growing body of clinical and electrophysiological research has examined the effects of Qur'anic recitation on anxiety, pain, autonomic tone, and cortical electrical activity in settings ranging from cardiac catheterization and coronary bypass recovery to labor and mechanical ventilation, generally reporting favorable effects on self-reported distress and physiological stress markers (Aburuz *et al*., 2023; Babaii *et al*., 2015; Ghiasi & Keramat, 2018) [1, 8, 17]. However, this literature has not yet been systematically connected to the specific neurophysiological demands and constraints of awake craniotomy.

This review therefore has three aims. First, to summarize the neurophysiological basis of consciousness monitoring and auditory processing during the altered states of arousal encountered in awake craniotomy. Second, to synthesize the evidence on auditory and music-based interventions for perioperative anxiety, and on Qur'anic recitation specifically, as a basis for evaluating its plausibility as a meaningful auditory stimulus in this context. Third, to propose an integrative conceptual model and to outline the practical and methodological considerations that would need to be addressed before such an intervention could be tested in awake craniotomy itself.

Neurophysiological Basis of Consciousness in Awake Craniotomy

1. Anesthetic Techniques and the Spectrum of Intraoperative Consciousness

The two dominant anesthetic strategies for awake craniotomy, asleep-awake-asleep (AAA) and monitored anesthesia care (MAC), differ mainly in whether the patient passes through a period of general anesthesia with a secured airway or is kept spontaneously breathing under titrated sedation for the entire procedure (Natalini *et al*., 2022; Sato & Nishiwaki, 2021) [30, 37]. Both techniques rely heavily on regional scalp nerve blockade of the supraorbital, supratrochlear, auriculotemporal, zygomaticotemporal, and occipital nerves to control the nociceptive stimulus of pin fixation, incision, and craniotomy, thereby reducing the systemic sedative and analgesic load required to keep the patient comfortable (Sato & Nishiwaki, 2021) [37]. Table 1 summarizes the principal features of the two approaches, both of which create extended windows in which the patient is neither fully anesthetized nor fully awake, and during which the auditory channel remains active.

Table 1: Comparison of the Asleep-Awake-Asleep and Monitored Anesthesia Care Techniques for Awake Craniotomy

Feature	Asleep-Awake-Asleep (AAA)	Monitored Anesthesia Care (MAC)
Airway management	General anesthesia with secured airway (LMA) during asleep phases; airway device removed for the awake phase	Spontaneous ventilation maintained throughout; no airway device required
Depth of sedation	Alternates between deep (general anesthesia) and near-baseline consciousness	Continuous light-to-moderate sedation titrated to task demands
Transition to awake phase	Abrupt emergence from general anesthesia; risk of agitation, delirium, or slower return of full cognitive function	Gradual, more predictable adjustment of consciousness level
Auditory environment relevance	Emergence phase is a period of heightened vulnerability to environmental sound and possible implicit auditory recall	Patient auditory awareness present throughout; continuous exposure to operating-room and instructional sound
Reported advantages	Greater airway control during the most stimulating surgical stages (craniotomy, dural opening)	Avoids risks of repeated airway manipulation; simpler logistics; often shorter time to reliable mapping
Reported disadvantages	Higher reported rates of airway complications and intraoperative psychological distress during transitions	Risk of inadequate analgesia or excessive sedation if not carefully titrated; dependent on effective scalp block

Note: Adapted from descriptions in Natalini *et al.* (2022), Sato and Nishiwaki (2021), and Meng *et al*. (2017) [26, 30, 37].

2. Monitoring the Level of Consciousness

Because the success of awake craniotomy depends on the patient reaching a reliably cooperative state, anesthesiologists rely on a combination of clinical scales and instrumented monitors. The Japan Coma Scale (JCS) provides a simple ordinal measure of arousal, with JCS 0-1 generally considered the threshold at which motor and language testing can proceed reliably (Umaba *et al*., 2022) [39]. The bispectral index (BIS), derived from processed frontal electroencephalography, is widely used as a continuous surrogate of cortical arousal and correlates with clinical measures such as hand-grip strength and predicted plasma propofol concentration during the awake phase, although its reliability can be degraded by electrical artifact from surgical equipment and by the anatomical constraints of frontal sensor placement in bilateral craniotomies

(Umaba *et al.*, 2022) [39]. Auditory evoked potential monitors constitute an alternative or complementary approach, since the latency and amplitude of auditory evoked responses vary systematically with anesthetic depth and can, in principle, provide information about consciousness even when frontal EEG-derived indices are unavailable (American Society of Anesthesiologists Task Force, 2006; Mou *et al.*, 2015) [5, 28].

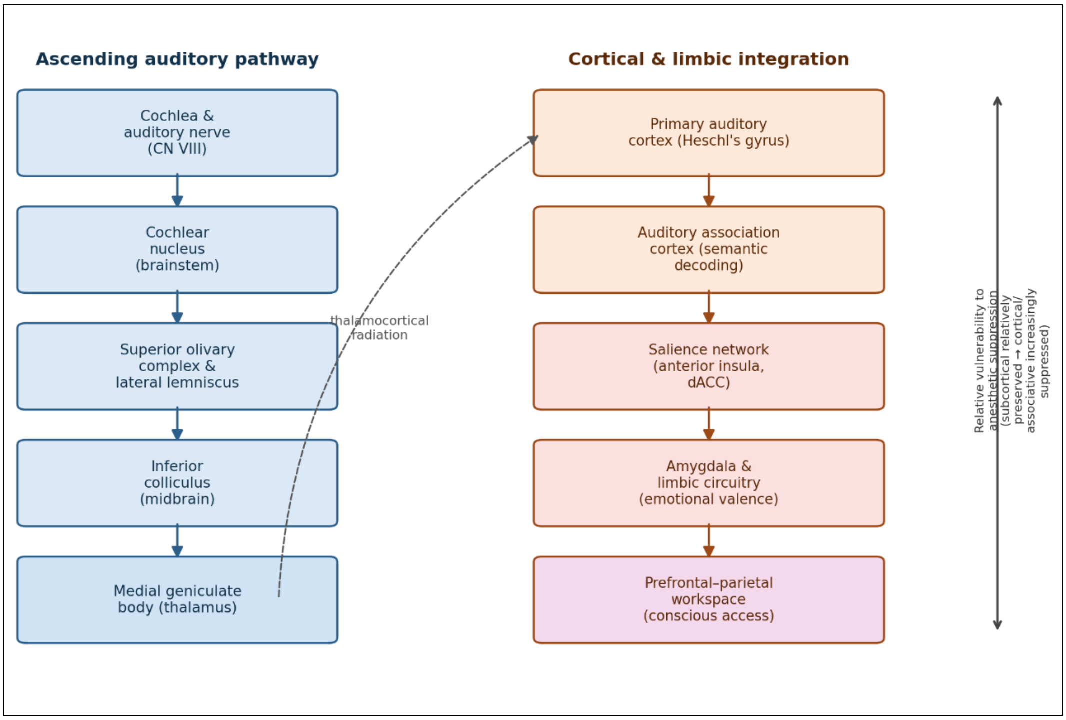
3. Theoretical Frameworks for Consciousness and Their Relevance to the Operating Room

Two influential theoretical frameworks help explain why auditory information can continue to be processed even when a patient is not fully conscious in the clinical sense. Global neuronal workspace theory proposes that a sensory representation becomes part of conscious experience only when it is non-linearly "broadcast" through long-range thalamocortical loops connecting sensory cortices with parietal and prefrontal association areas; representations that remain confined to local sensory cortex can be processed, and can influence behavior or memory implicitly, without reaching conscious report (Baars, 2005) [7]. Integrated information theory instead emphasizes the degree of information integration within posterior cortical networks as the defining feature of conscious content. Anesthetic and sedative agents are understood, within both frameworks, to act primarily by disrupting long-range cortical connectivity and thalamocortical communication while comparatively sparing local sensory processing, which is consistent with the persistence of early- and middle-latency auditory evoked responses even at surgical planes of anesthesia (Baars, 2005; Alkire *et al.*, 2008) [4, 7]. This distinction between the level of arousal (wakefulness) and the contents of consciousness (what is being represented) is directly relevant to awake craniotomy, where clinicians must repeatedly distinguish a patient who is behaviorally quiet but covertly processing auditory information from a patient who has genuinely lost the capacity for conscious auditory perception.

The Auditory System as a Privileged Channel During Altered Consciousness

1. Anatomical and Functional Organization of the Ascending Auditory Pathway

Sound is transduced by cochlear hair cells and relayed through a multisynaptic ascending pathway that passes through the cochlear nucleus, superior olivary complex, lateral lemniscus, inferior colliculus, and medial geniculate body of the thalamus before reaching primary auditory cortex in Heschl's gyrus and, from there, auditory association cortex and a wide array of limbic and paralimbic structures (Figure 1). This multisynaptic architecture is clinically important because general anesthetics and sedatives do not suppress all levels of this pathway uniformly: subcortical and early cortical components tend to be relatively preserved, whereas the later, more integrative cortical and associative responses are progressively attenuated as anesthetic depth increases (American Society of Anesthesiologists Task Force, 2006; Mou *et al.*, 2015) [5, 28]. This graded vulnerability is the physiological basis for the clinical observation that patients can retain some capacity for auditory processing, and occasionally for implicit memory of intraoperative sound, even under general anesthesia (Osterman *et al.*, 2001, as cited in Mou *et al.*, 2015) [28, 31].



Note: Schematic synthesis based on descriptions of the auditory pathway and its differential sensitivity to anesthetic agents in Mou *et al.* (2015) [28], the American Society of Anesthesiologists Task Force on Intraoperative Awareness (2006), and Laureys *et al.* (2000) [5, 23].

Fig 1: Ascending Auditory Pathway and Cortical-Limbic Integration, with Relative Vulnerability to Anesthetic Suppression

2. Evidence That Auditory Processing Persists During Sedation and Anesthesia

Direct electrophysiological evidence for continued auditory processing during reduced consciousness comes from several converging lines of research. Auditory evoked potentials (AEPs), classified by latency into early (brainstem), middle-latency, and late cortical components, have long been used as indices of anesthetic depth precisely because their morphology changes in a dose-dependent manner with sedative and anesthetic agents rather than disappearing outright (Mou *et al*., 2015) [28]. Middle-latency auditory evoked responses (MLAERs) recorded during postoperative propofol sedation have been shown to predict which patients retain subconscious processing of narrated stories played during apparent unconsciousness, with implicit memory more likely when Pa-wave latency remained close to the awake baseline (Ypparila *et al*., 2002) [40]. Event-related potential components such as the mismatch negativity and P3a, which index automatic detection of auditory deviance, have been documented across sleep, sedation, and disorders of consciousness, suggesting that pre-attentive auditory discrimination is one of the most resilient forms of information processing in the reduced-consciousness brain (Mou *et al*., 2015) [28].

Perhaps the most striking demonstration of preserved auditory processing comes from patients in the vegetative state, in whom functional imaging shows that primary auditory cortex remains responsive to simple sound but loses the functional connectivity with associative and prefrontal regions that would normally support conscious perception of meaning (Laureys *et al*., 2000) [23]. Neuroimaging work across the natural sleep-wake cycle similarly demonstrates that auditory cortical responses to external sound persist across sleep stages while their coupling with higher-order association areas fluctuates with the depth of unconsciousness (Portas *et al*., 2000) [33]. This dissociation between low-level cortical activation and higher-order integration mirrors, at a much more severe end of the spectrum, the pattern seen during surgical sedation, and reinforces the concept that a stimulus can be neurally registered without being consciously experienced or, conversely, can be registered and later influence affect or memory through implicit routes even when explicit recall is absent (Mou *et al*., 2015) [28]. Consistent with this, population-level studies of general anesthesia have found that explicit intraoperative awareness with recall, although uncommon, is disproportionately associated with auditory rather than visual or tactile content, and carries a documented risk of later psychological sequelae including post-traumatic stress symptoms (Osterman *et al*., 2001; Ranta *et al*., 1998) [31, 35], further underscoring that the auditory channel is not neurophysiologically or psychologically inert even when patients are believed to be unconscious. Continuous processed-EEG signatures used clinically to track anesthetic depth, including spectral changes associated with loss and return of consciousness, provide a further, non-auditory-specific illustration of how graded, quantifiable cortical states underlie the clinical categories of "asleep" and "awake" that anchor awake craniotomy protocols (Purdon *et al*., 2015) [34].

3. Emotional and Semantic Salience: Why Not All Sounds Are Processed Equally

Auditory input is not processed as an undifferentiated acoustic signal; primary and secondary auditory cortices are anatomically and functionally connected to limbic and paralimbic structures, including the amygdala, anterior insula, and cingulate cortex, that assign emotional salience to sound (Koelsch *et al*., 2018) [20]. Functional imaging using emotionally contrasting musical stimuli has shown that regions of auditory association cortex occupy influential, highly connected positions within emotion-processing brain networks, indicating that the auditory cortex is not merely a passive relay but an active participant in generating affective responses to sound (Koelsch *et al*., 2018) [20]. Pleasant and unpleasant sounds recruit at least partially distinct circuits, with reward-related regions such as the ventromedial prefrontal cortex and nucleus accumbens more engaged by pleasant stimuli, and the amygdala and insula more engaged by aversive or emotionally arousing sound (Koelsch *et al*., 2018) [20]. Because these limbic connections are established at early stages of the auditory hierarchy, a familiar, emotionally positive, or spiritually meaningful stimulus is plausible to engage affect-regulating circuitry even under conditions in which higher-order semantic analysis is degraded, distinguishing it in principle from acoustically similar but emotionally neutral background noise.

This principle has direct relevance to the operating room. Environmental noise in surgical settings, generated by monitors, suction, drills, and staff conversation, is a well-documented stressor: measured decibel levels during many common procedures regularly exceed recommended occupational limits (Baltin *et al*., 2020) [10], and higher intraoperative noise has been associated with increased staff anxiety, degraded communication, and even adverse patient outcomes such as surgical-site infection in day-case surgery (Dholakia *et al*., 2015) [15], while patients themselves frequently describe intraoperative noise as distressing when interviewed postoperatively (Padmakumar *et al*., 2017) [32]. Broader reviews of the sensory environment of complex healthcare settings similarly emphasize that uncontrolled ambient stimuli, of which sound is one of the most pervasive, act as a chronic physiological stressor rather than a neutral backdrop (Bayramzadeh *et al*., 2021) [11]. Notably, even the acoustic noise generated by neuroimaging hardware itself has been shown to interact measurably with affective neural processing of emotional auditory stimuli (Skouras *et al*., 2013) [38], illustrating that background sound and meaningful sound are not processed independently but can interact within the same limbic and auditory circuitry. Because the auditory cortex remains active and receptive even under general anesthesia, uncontrolled operating-room noise is not neurophysiologically inert for the patient, even when the patient later has no explicit memory of it; this observation has been used to argue that the auditory environment of surgery deserves active management rather than passive tolerance. In the specific context of awake craniotomy, where the patient is by definition able to perceive and often explicitly remember much of the intraoperative period, this concern is amplified rather than diminished.

Psychological Burden and Auditory Interventions in the Perioperative Setting

1. The Psychological Demands of Awake Craniotomy

Awake craniotomy imposes a distinctive psychological burden that is qualitatively different from most other surgical experiences: the patient is aware, often for one to several hours, of being physically restrained, of undergoing a procedure on their own brain, and of hearing the unfiltered sounds of drilling, suction, and clinical conversation. Fear, anxiety, and pain are consistently reported as the most common intraoperative psychological phenomena, and preoperative anxiety has been shown to correlate with postoperative pain and functional interference even when it does not directly predict intraoperative pain itself (Milian *et al*., 2014) [27]. In a large single-center retrospective analysis, intraoperative anxiety and younger patient age were identified as independent risk factors for panic attacks severe enough to threaten the completion of awake mapping, underscoring that psychological decompensation is not a rare curiosity but a recognized clinical complication with the potential to convert an awake procedure to general anesthesia (Milian *et al*., 2014) [27]. Because panic and severe anxiety can directly compromise the reliability of language and motor testing, and because pharmacological anxiolysis carries the risk of blunting consciousness below the threshold required for mapping, there has been longstanding clinical interest in non-pharmacological strategies, most centrally psychological preparation, a trusting patient-clinician relationship, and careful management of the intraoperative sensory environment, to reduce fear without sedation (Milian *et al*., 2014; Sandhu & Dash, 2009) [27, 36].

2. Evidence for Music and Meaningful Sound as Perioperative Interventions

Outside the specific context of awake craniotomy, a substantial and consistent evidence base supports auditory interventions, chiefly recorded or live music, as a means of reducing perioperative anxiety and pain. A large meta-analysis pooling numerous randomized controlled trials across surgical specialties found that music interventions produced small-to-moderate but statistically robust reductions in anxiety and pain, whether delivered before, during, or after surgery (Kühlmann *et al*., 2018) [22]. Specialty-specific meta-analyses in gynecological, ophthalmic, orthopedic, otolaryngologic, and renal surgery have generally replicated this pattern, reporting reductions in validated anxiety instruments such as the State-Trait Anxiety Inventory, lower visual analog pain scores, and, in some analyses, favorable changes in heart rate and blood pressure consistent with reduced sympathetic activation. Table 2 summarizes representative findings from this broader surgical literature alongside findings specific to Qur'anic recitation, discussed further in Section 5.

Table 2: Representative Evidence for Music-Based and Qur'anic Auditory Interventions Across Surgical and Clinical Contexts

Surgical Context	Reported Outcome Measures	Summary of Findings
Mixed surgical specialties (meta-analysis)	Anxiety and pain scores, pooled across trials	Small-to-moderate reductions in perioperative anxiety and pain across surgical types (Kühlmann *et al*., 2018)
Gynecological surgery	STAI anxiety score; postoperative pain	Significant reduction in preoperative anxiety and postoperative pain with music exposure
Ophthalmic surgery	VAS anxiety risk; STAI-S; intraoperative pain	Reduced risk of high anxiety and lower STAI-S and pain scores with low heterogeneity across studies
Orthopedic surgery	Pain (SMD); anxiety (SMD); opioid use	Significant reduction in both pain and anxiety across randomized and quasi-experimental studies
Otolaryngologic surgery	Pre-, peri-, and postoperative anxiety and pain; heart rate; blood pressure	Consistent reduction in anxiety and pain, with favorable autonomic (heart rate, blood pressure) changes
Cardiac catheterization (Qur'anic recitation)	Pre-procedural anxiety (self-report)	Significant reduction in anxiety before catheterization in the recitation group (Babaii *et al*., 2015) [8]
Post-CABG recovery (Qur'anic recitation)	Pain intensity; ICU and hospital length of stay	Reduced pain scores and shorter ICU/hospital stay with twice-daily recitation exposure (Aburuz *et al*., 2023) [1]
Healthy adults, resting stress paradigm (Qur'anic recitation)	Electromyogram, skin conductance, heart rate biofeedback	Lower biofeedback stress indices in the recitation group relative to control
Labor (Qur'anic recitation)	Pain, maternal comfort, blood pressure	Reduced pain, improved comfort, and more stable blood pressure in nulliparous women

Note: STAI = State-Trait Anxiety Inventory; STAI-S = State-Trait Anxiety Inventory, State subscale; VAS = Visual Analog Scale; SMD = standardized mean difference; CABG = coronary artery bypass graft. Sources as cited in each row.

The proposed mechanisms underlying these effects converge on two interacting systems. First, pleasant or personally meaningful auditory stimuli are thought to reduce activation of the hypothalamic-pituitary-adrenal axis, lowering circulating cortisol and adrenocorticotropic hormone, and to shift autonomic balance toward parasympathetic dominance, reflected in reduced heart rate and blood pressure and increased heart-rate variability (Universa Medicina RCT findings, see Section 5.2). Second, at a central level, meaningful sound is thought to compete for attentional and limbic resources with threat-related and nociceptive processing, effectively providing a cognitive and affective distraction that reduces the perceived intensity of both anxiety and pain (Koelsch *et al*., 2018) [20]. Notably, several reviews have found that patient-selected or personally familiar music tends to outperform researcher-selected or unfamiliar music in reducing anxiety, suggesting that the degree of personal or cultural meaning carried by a sound, rather than its acoustic properties alone, is an important moderator of its therapeutic effect.

3. The Uncontrolled Auditory Environment as a Confound

A parallel and complementary literature has documented the harms of uncontrolled operating-room noise. Ambient sound levels in many operating rooms regularly exceed recommended occupational limits, and higher measured noise has been associated with increased staff stress and cognitive load, impaired team communication, and, in several studies, a higher incidence of surgical-site infection (Padmakumar *et al*., 2017) [32]. From the patient's perspective, postoperative interviews consistently identify intraoperative noise as a source of distress, and, as discussed in Section 3, there is direct electrophysiological evidence that the auditory cortex remains responsive to such noise even when patients are sedated or anesthetized. Within awake craniotomy specifically, where the patient is by definition capable of consciously perceiving this noise for a prolonged period, the case for deliberately curating rather than passively tolerating the auditory environment is correspondingly stronger. This provides the clinical rationale for considering a specific, culturally salient auditory intervention, Qur'anic recitation, as a candidate replacement or supplement to the default, uncontrolled soundscape of the operating room.

Qur'anic Recitation as a Meaningful Auditory Stimulus

1. Sources of Meaning: Linguistic, Rhythmic, and Spiritual Salience

Interest in religiosity and spiritual practice as a determinant of mental health has a substantial evidence base beyond the Qur'an-specific literature: broad evidence-based reviews of religious involvement have generally found positive associations with outcomes such as depression, substance use, and suicide risk, providing a wider frame within which the more specific literature on Qur'anic recitation can be situated (Bonelli & Koenig, 2013).

Qur'anic recitation (tilawah) differs from most auditory stimuli studied in the perioperative literature in that it combines several dimensions of salience simultaneously. Acoustically, tajweed recitation follows precise, rule-governed patterns of rhythm, pitch modulation, and elongation that give it a musical, almost prosodic quality distinct from ordinary speech. Linguistically and semantically, for a practicing Muslim listener the recited text carries specific, often deeply familiar meaning, reinforced by a lifetime of religious education and repeated exposure. Spiritually and culturally, the Qur'an occupies a position of profound reverence and personal significance, such that listening is frequently associated with feelings of comfort, trust, and surrender that are qualitatively distinct from the aesthetic pleasure evoked by music in general (Che Wan Mohd Rozali *et al*., 2022) [13]. Because auditory-limbic connections are sensitive to exactly this kind of layered emotional and semantic salience (Koelsch *et al*., 2018) [20], Qur'anic recitation represents a theoretically well-motivated candidate for a therapeutically meaningful auditory stimulus in Muslim patients, over and above its acoustic properties as a form of vocal or musical sound.

2. Neurophysiological and Autonomic Evidence

A cluster of small experimental studies using scalp electroencephalography has reported that listening to Qur'anic recitation increases alpha-band power relative to a resting baseline and, in comparative designs, relative to fast-tempo or "hard" music conditions, a pattern generally interpreted as reflecting a state of wakeful relaxation (Javed *et al*., 2023) [19]. An early comparative EEG study similarly found that listening to Qur'anic recitation produced greater increments in alpha-band coherence than listening to classical music among healthy young adults (Zulkurnaini *et al*., 2012) [41], and subsequent work applying a valence-arousal emotion-recognition framework to EEG signals reported that recitation was associated with a more consistently low-arousal, positive-valence pattern than relaxing music comparators (Al-Galal *et al*., 2015) [2]. In a controlled comparison among healthy medical students, alpha wave increments were significantly greater during exposure to a recited chapter of the Qur'an than during exposure to classical music, suggesting that the relaxation-associated cortical signature may not simply track generic musicality but may be specifically enhanced by the additional linguistic and spiritual salience of recitation for Muslim listeners (Javed *et al*., 2023) [19]. Complementary evidence from peripheral biofeedback recordings, including electromyography, galvanic skin conductance, and heart rate, has shown reduced composite stress indices in healthy adults randomized to listen to recitation compared with a non-exposed control group, consistent with a shift toward parasympathetic autonomic dominance and broadly in line with the general utility of skin-conductance and related biofeedback markers as indices of autonomic stress reactivity (Hanafi *et al*., 2024; Nagai *et al*., 2019) [18, 29]. Several authors have further proposed that recitation lowers circulating cortisol and adrenocorticotropic hormone, implicating attenuation of hypothalamic-pituitary-adrenal axis activity as a plausible neuroendocrine correlate of the observed reductions in subjective stress; consistent with this, recitation exposure has also been associated with broader indices of improved mental health and well-being in occupational and community samples (Mahjoob *et al*., 2016) [24], although the hormonal pathway itself has been assessed in fewer controlled trials than the behavioral and autonomic outcomes. Heart-rate variability, a marker increasingly used as a general index of autonomic and mental-fatigue states in other clinical contexts (Csathó *et al*., 2024) [14], represents a promising but still underused outcome measure for future recitation studies, since it would allow more direct comparison with the autonomic endpoints already reported in the broader perioperative music-intervention literature summarized in Section 4.

3. Clinical Evidence Across Procedural and Perioperative Contexts

Beyond laboratory electrophysiology, a growing number of randomized and quasi-experimental clinical trials have examined Qur'anic recitation as an adjunctive intervention in procedural and perioperative care. Among patients awaiting cardiac catheterization, recitation exposure produced a significant reduction in pre-procedural anxiety compared with usual care (Babaii *et al*., 2015) [8]. In patients recovering from coronary artery bypass grafting, twice-daily recitation sessions were associated with significantly lower pain scores and shorter intensive care unit and total hospital stay relative to controls (Aburuz *et al*., 2023) [1]. In mechanically ventilated patients, recitation of Surah Yasin was associated with more favorable hemodynamic parameters, suggesting that the physiological effect does not require the patient to be fully conscious in the ordinary sense, an observation directly relevant to the sedated and semi-conscious states encountered during awake craniotomy. In obstetric care, recitation during labor has been associated with reduced pain, improved maternal comfort, and more stable blood pressure among nulliparous women in a quasi-experimental comparison. Table 3 consolidates the principal outcome domains and representative findings reported across this literature.

Table 3: Summary of Reported Neurophysiological, Autonomic, and Clinical Effects of Qur'anic Recitation

Domain	Instrument / Marker	Representative Reported Findings
Cortical electrical activity	EEG alpha-band power	Increased alpha-band power during recitation relative to rest and relative to comparison music conditions, interpreted as a relaxation-associated cortical signature (Javed *et al*., 2023) [19]
Autonomic nervous system	Electromyogram, skin conductance, heart rate (biofeedback)	Lower composite stress-biofeedback indices among healthy adults exposed to recitation compared with a non-exposed control group in a randomized design
Neuroendocrine axis	Cortisol, adrenocorticotropic hormone (ACTH)	Recitation exposure proposed to lower circulating cortisol and ACTH, consistent with reduced hypothalamic-pituitary-adrenal axis activation
Self-reported anxiety	STAI and related anxiety scales	Systematic reviews report consistent reductions in anxiety across a range of clinical populations, including pre-procedural, hemodialysis, and cancer-treatment settings (Ghiasi & Keramat, 2018; Che Wan Mohd Rozali *et al*., 2022) [13, 17]
Perioperative / procedural pain	Visual analog scale pain scores	Reduced pain intensity reported after coronary artery bypass grafting and during labor with recitation exposure (Aburuz *et al*., 2023) [1]
Cardiovascular / hemodynamic parameters	Heart rate, blood pressure	Improved hemodynamic stability reported in mechanically ventilated patients and in laboring women exposed to recitation
Quality of life / sleep	Quality of life and sleep-quality instruments	Favorable associations between habitual Qur'an engagement (listening, reciting, memorizing) and self-reported quality of life and sleep quality (Che Wan Mohd Rozali *et al*., 2022) [13]

Note: STAI = State-Trait Anxiety Inventory. Findings summarized from primary studies and systematic/scoping reviews cited in each row; effect sizes vary across studies and populations and should be interpreted with the methodological caveats discussed in Section 8.

4. Synthesis Across Systematic Reviews

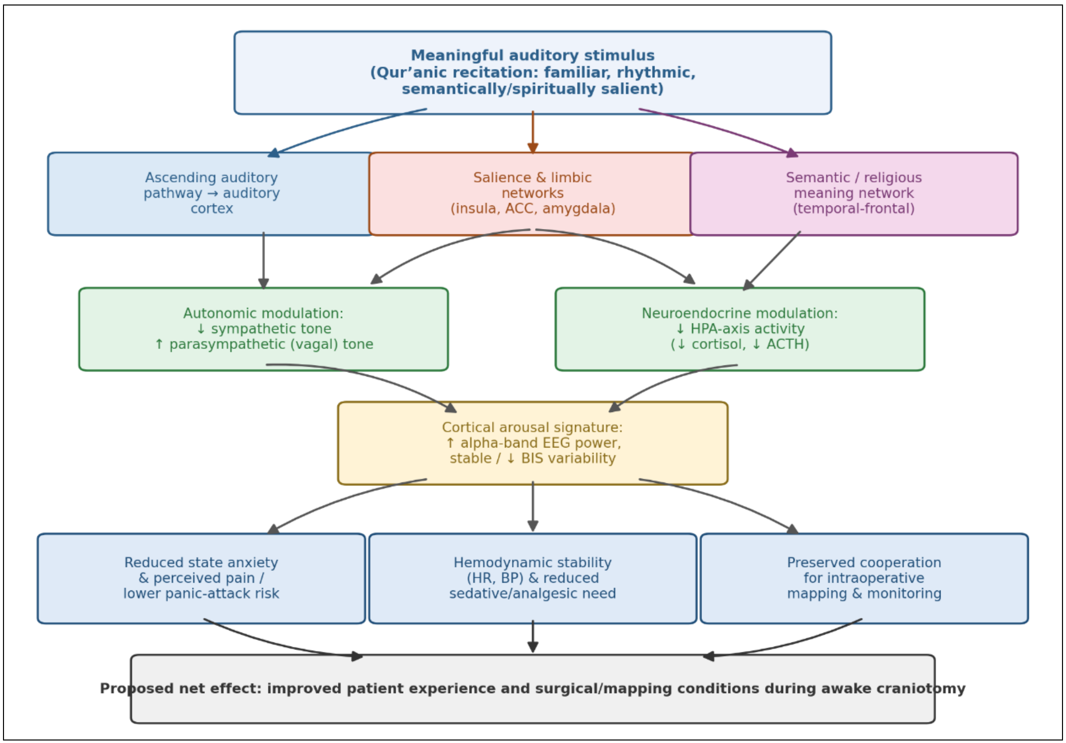
At least three independent systematic or scoping reviews have now synthesized this primary literature. A systematic review focused specifically on anxiety outcomes concluded that Qur'anic recitation and listening produced consistent reductions in self-reported anxiety across the majority of included trials, spanning pre-procedural, hemodialysis, and general clinical populations (Ghiasi & Keramat, 2018) [17].

A broader systematic review of listening, reciting, and memorizing the Qur'an, which included twenty studies drawn from more than two hundred initially identified records, reported favorable associations not only with anxiety but also with depression, physiological stress parameters, quality of life, sleep quality, and, among habitual memorizers, measures of cognitive performance (Che Wan Mohd Rozali *et al*., 2022) [13].

A separate scoping review restricted to anxiety, stress, and depression outcomes similarly concluded that recitation and listening constitute a simple, low-cost, and low-risk non-pharmacological adjunct across the populations studied, while explicitly noting that all included primary studies originated from countries in Asia and that methodological quality varied considerably, from small non-blinded trials to larger randomized designs. Taken together, these reviews support the general plausibility of Qur'anic recitation as a stress- and anxiety-modulating auditory intervention, while highlighting that the evidence base remains geographically and methodologically narrow, and, critically for the purposes of this review, has not yet been extended into the intraoperative neurosurgical setting.

A Proposed Neurophysiological Model for Integrating Meaningful Auditory Stimulation into Awake Craniotomy

Drawing together the neurophysiology of auditory processing under altered consciousness (Section 3), the clinical evidence for auditory interventions in surgery generally (Section 4), and the specific evidence base for Qur'anic recitation (Section 5), a conceptual model can be proposed to explain how a meaningful auditory stimulus might, in principle, influence the patient's experience and physiological stability during awake craniotomy (Figure 2). In this model, a familiar, rhythmic, and semantically and spiritually salient auditory stimulus is processed simultaneously along three parallel routes: the standard ascending auditory pathway to auditory cortex; the salience and limbic network, comprising the anterior insula, dorsal anterior cingulate cortex, and amygdala, which assigns emotional weight to the stimulus (Koelsch *et al*., 2018) [20]; and, for a stimulus with linguistic and religious content, a semantic and meaning-processing network distributed across temporal and frontal language regions. These three parallel streams are proposed to converge on two mediating physiological systems: autonomic modulation, favoring reduced sympathetic and increased parasympathetic tone, and neuroendocrine modulation, favoring reduced hypothalamic-pituitary-adrenal axis activity and lower circulating cortisol, consistent with the autonomic and hormonal findings reviewed in Sections 4 and 5. The convergence of these mediating systems is hypothesized to produce a measurable cortical arousal signature, such as increased alpha-band EEG power or a more stable bispectral index, which in turn is associated with three clinically relevant downstream outcomes: reduced state anxiety and perceived pain, improved hemodynamic stability with reduced sedative or analgesic requirement, and, critically for awake craniotomy, preserved patient cooperation for intraoperative language and motor mapping.



Note: This is a theoretical synthesis derived from the neurophysiological and clinical literature reviewed in Sections 3-5 (Koelsch *et al*., 2018; Javed *et al*., 2023; Aburuz *et al*., 2023; Babaii *et al*., 2015; Che Wan Mohd Rozali *et al*., 2022) [1, 8, 13, 19, 20] and has not itself been directly tested within awake craniotomy; it is offered as a framework to guide future hypothesis-driven research rather than as an established causal pathway.

Fig 2: Proposed Conceptual Model of Meaningful Auditory Stimulation (Qur'anic Recitation) During Awake Craniotomy

Clinical and Practical Considerations for Future Implementation

Translating this conceptual model into a safe and methodologically sound clinical protocol raises several practical considerations that distinguish awake craniotomy from the more general perioperative contexts in which auditory interventions have previously been studied.

1. Timing Relative to Intraoperative Mapping

The single most important constraint is that language and speech-arrest mapping, by definition, requires an auditory channel free of competing verbal or strongly rhythmic auditory input during the discrete testing epochs themselves, since concurrent recitation could plausibly interfere with the patient's ability to hear and respond to naming, counting, or reading tasks, or could confound the interpretation of speech arrest induced by direct cortical stimulation (Kombos & Süss, 2009) [21].

Any protocol would therefore need to restrict recitation to the pre-mapping and inter-task intervals, for example during scalp block placement, craniotomy, and dural opening, and to pause playback during the discrete stimulation-mapping epochs, resuming once each mapping segment is complete.

2. Delivery Method and Volume Control

Delivery through a single-ear insert or low-volume speaker positioned away from the surgical field would need to be calibrated so that recitation remains audible to the patient without masking verbal instructions from the anesthesiologist, neurophysiologist, or surgeon, or interfering with communication among the operative team, echoing concerns raised in the broader operating-room noise literature about the balance between beneficial and disruptive sound (Padmakumar *et al*., 2017) [32].

3. Patient Selection, Consent, and Cultural Fit

Because the therapeutic model proposed here rests substantially on personal, cultural, and spiritual meaning rather than on acoustic properties alone, the intervention is inherently patient-specific: it would be expected to be most relevant for practicing Muslim patients who have a pre-existing positive association with Qur'anic recitation, and should be offered, not assumed, as part of a broader discussion of preferences during preoperative counseling, consistent with the existing emphasis on individualized psychological preparation in the awake craniotomy literature (Milian *et al*., 2014) [27].

4. Integration with Existing Anesthetic and Monitoring Protocols

A future study would need to specify clearly how recitation exposure interacts with the anesthetic technique chosen (AAA vs. MAC; Table 1), and would benefit from capturing the same physiological endpoints already used to monitor consciousness and stress during awake craniotomy, namely BIS, heart rate variability, and where feasible frontal EEG alpha power, so that any auditory intervention effect can be directly related to the monitoring parameters clinicians already use at the bedside (Umaba *et al*., 2022) [39]. Because MAC and AAA differ in the proportion of the procedure spent under deep sedation versus light monitored sedation (Eseonu *et al*., 2017) [16], the two techniques may also differ in how much of the case is available for auditory intervention and in how directly any observed effect can be attributed to the stimulus rather than to the anesthetic background against which it is delivered, a distinction that future protocols should stratify for explicitly.

Limitations of the Current Evidence and Directions for Future Research

Several important limitations qualify the conceptual model proposed above and should guide the design of future studies.

- No published study has directly tested Qur'anic recitation, or any comparably meaningful auditory stimulus, within the specific setting of awake craniotomy; the model in Section 6 is therefore a synthesis of adjacent literatures rather than a validated clinical pathway.
- Existing Qur'anic recitation studies are geographically concentrated in a small number of Asian and Middle Eastern countries, use heterogeneous outcome measures, and frequently rely on small samples and non-blinded or quasi-experimental designs, limiting the strength of causal inference (Che Wan Mohd Rozali *et al*., 2022) [13].
- Most electrophysiological studies of Qur'anic recitation report EEG findings from healthy resting participants rather than from patients under sedation or anesthesia, so the persistence and magnitude of any alpha-power or autonomic effect specifically during the pharmacologically altered states used in awake craniotomy remains unverified.
- Comparative designs have not consistently isolated the contribution of semantic and spiritual meaning from the acoustic and prosodic features of recitation; dismantling studies comparing recitation, comprehensible translation without melodic recitation, and acoustically matched non-semantic control sounds would help clarify which components drive the observed effects.
- Potential interference between recitation and the auditory demands of intraoperative language mapping has not been empirically tested and represents the most safety-relevant open question before any clinical trial in awake craniotomy could proceed (Kombos & Süss, 2009) [21].
- Publication bias favoring positive findings is a recognized concern across the broader perioperative music-intervention literature and cannot be excluded in the Qur'anic recitation literature specifically, given the predominance of small, single-center trials.

Addressing these gaps would require prospective, ideally randomized, studies conducted within awake craniotomy protocols that combine standard consciousness and stress monitoring (BIS, JCS, heart rate variability, and where feasible frontal EEG) with validated psychological outcome measures and structured assessment of any interference with language and motor mapping accuracy, alongside qualitative assessment of patient experience.

Conclusion

Awake craniotomy places unique demands on the auditory system, requiring patients to remain reliably responsive to verbal instruction across shifting states of pharmacologically modulated consciousness, while simultaneously exposing them, often with full or partial awareness, to a surgical soundscape that is not designed with their psychological comfort in mind. Neurophysiological evidence indicates that auditory processing, particularly its subcortical and early cortical components, is comparatively resistant to suppression by sedative and anesthetic agents, and that the emotional and semantic salience of a sound, not merely its acoustic properties, engages limbic and associative circuitry capable of influencing autonomic and neuroendocrine stress responses. A substantial evidence base supports music and other meaningful auditory stimuli as effective, low-risk adjuncts for reducing perioperative anxiety and pain across many surgical specialties, and a smaller but growing body of clinical and electrophysiological research suggests that Qur'anic recitation, as a linguistically, rhythmically, and spiritually salient stimulus for Muslim patients, produces measurable reductions in anxiety, pain, and physiological stress markers across diverse clinical settings. Integrating these two literatures suggests a biologically plausible and clinically motivated rationale for evaluating Qur'anic recitation as a structured, carefully timed auditory adjunct within awake craniotomy protocols, particularly in Muslim-majority health systems such as Indonesia's. Realizing this possibility responsibly will require dedicated prospective research that directly measures its effects on consciousness monitoring parameters, psychological distress, and, most importantly, the accuracy and safety of intraoperative language and motor mapping, before any such intervention can be recommended for routine clinical use.

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