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Review Article

Anaesthesia Section

Awake Craniotomy in Drug-resistant Epilepsy: A Narrative Review of Clinical Principles, Perioperative Management, and Emerging Advances

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ABSTRACT

Drug-Resistant Epilepsy (DRE) affects usually one-third of patients having epilepsy who fail to achieve seizure freedom despite trials of two or more appropriately chosen and tolerated Antiseizure Medications (ASM). Persistent seizures in DRE further contribute to significant neurological, cognitive, psychosocial morbidity, thereby emphasising need for timely identification as well as alternative therapeutic strategies. Surgical intervention, which is done in cases where epileptogenic foci are located near eloquent cortical regions, has emerged as a critical management option. Awake Craniotomy (AC) has also gained prominence into its application for DRE surgery because of its ability to combine maximal resection of epileptogenic zones along with real-time functional mapping, thereby preserving essential neurological functions inclusive of language, motor control and cognition. This narrative review explores clinical and neurodiagnostic determinants guiding candidacy for AC, perioperative anaesthetic strategies, intraoperative monitoring, selection of patients also postoperative care of patients. Asleep-Awake-Asleep (SAS) and Awake-Awake-Awake (AAA) protocols are discussed in brief highlighting their advantages, limitations along with their anaesthetic implications. Special emphasis is placed on preoperative psychological preparation of patients usually in paediatric populations, and role of multidisciplinary teams for optimising intraoperative cooperation with improvement of outcomes. The narrative review article also highlights emerging innovations like high-density Electrocorticography (ECoG) grids, Real-Time Functional brain Mapping (RTFM), as well as Corticocortical Evoked Potentials (CCEP), which helps to enhance the accuracy of intraoperative mapping and reduce postoperative deficits. Through integration of established evidence with novel techniques, AC can prove as a precision-based, function-preserving surgical approach which can help in maximising seizure control while minimising neurological deficit in patients. This narrative review underscores evolving role of AC in management of DRE thus emphasising its potential for improving patient outcomes and quality of life in complex type of clinical cases.

Keywords: Brain mapping, Cortical stimulation, Neurostimulation, Patient selection, Seizure control

INTRODUCTION

Epilepsy is a chronic neurological disorder which affects more than 50 million people worldwide, with an estimated 4.9 million new cases diagnosed each year [1,2]. ASMs are the main pillars of the treatment and they effectively suppress or minimally reduce the number of seizures in a large group of patients [2]. However, approximately one-third of people with epilepsy do not achieve seizure freedom despite trials of appropriately chosen and tolerated medications referred as DRE, sometimes also called refractory or medically intractable epilepsy [3]. Accurate, standardised definition of DRE is very essential for informed clinical decision-making as well as for ensuring the validity and comparability of epidemiological studies [3]. The burden in DRE patients is high. Persistent seizures not only result in morbidity due to injury, neurological decline, psychosocial effects, increased mortality, and reduced quality of life, but also increased health care utilisation [4]. The importance of early detection of DRE is highlighted in most of the recent reviews so that alternative treatment strategies, including surgery, can be considered in time [4,5]. The International League Against Epilepsy (ILAE) published a consensus definition of DRE in 2009; inability of two well-chosen and tolerated antiseizure drugs schedules (mono- or polytherapy) to produce sustained seizure freedom [6]. Epidemiology studies conducted in parallel revealed that about 30 percent of epilepsy patients pass the criteria of DRE, but the estimates depend on the population of patients (e.g., community-based, clinic-based) and age group [4,7,8].

The surgical intervention has emerged as one of the critical therapy options given the high burden of disease along with the low efficacy of pharmacotherapy in DRE [9]. AC has become an important method of DRE surgery, especially when the epileptogenic focus falls within close proximity to eloquent cortical regions involved in either motor, language, or sensory functions [9]. AC allows real-time mapping in the cortex and avoids the disruption of the essential functions of the brain, which enables the accurate resection of epileptogenic focus resulting in increased seizure control and functional outcomes [9,10]. The narrative review article aims to outline clinical rationale, selection of patients, perioperative and anaesthetic considerations, surgical approaches as well as emerging innovations focusing on AC into the management of DRE thus highlighting its role in optimising seizure control while also preserving neurological functionality in patients.

Clinical and Neurodiagnostic Features of Drug-Resistant Epilepsy (DRE)

The most common definition of DRE is the inability to attain sustained control of seizures despite trials of two or more ASMs of appropriate choice and tolerability [11]. Clinically, patients with DRE tend to, as the disease progresses, develop more serious patterns of seizures: frequent seizures (usually multiple per day), mixed seizure types (focal and generalised, or a combination of both), previous history of status epilepticus, neonatal seizures, both febrile and afebrile seizures [12]. These initial characteristics differentiate them compared to drug-responsive cases which tend to start later

in life, have more homogenous seizure types, and have less burden of seizure per day [12].

Along with the features of seizures, patients usually present with associated neurological deficits and radiological abnormalities, which are commonly linked to drug resistance [13]. Many patients show evidence of abnormal neurodevelopment, intellectual disability, motor developmental delay or retardation, neurological deficits on examination and often have symptomatic or structural aetiologies detectable on neuroimaging (e.g., cortical or hippocampal abnormalities) [14,15]. On EEG, typical results comprise of the anomalies in the initial EEG: epileptiform discharges, generalised epileptic abnormalities, slow wave background changes, or multifocal epileptiform activity [16].

Patients having DRE usually exhibit a progressive clinical burden which is characterised by psychiatric comorbidities, including depression, anxiety, behavioural disturbances, and impaired psychosocial functioning [17]. All of these comorbidities are being increasingly known as intrinsic components of the epileptic network rather than mere consequences of recurrent seizures [17,18]. Cognitive decline which is usually inclusive of executive function, memory, attention, can further evolve over time which is also often disproportionate to seizure frequency alone, suggesting widespread network dysfunction [18]. Such clinical features are associated strongly having early disease onset, long-standing epilepsy duration, as well as underlying structural or genetic aetiologies, all of which correlate to poorer responsiveness to treatment also poor surgical outcomes [18].

Advanced imaging as well as electrophysiological techniques provides very important insights into the network-level abnormalities underlying DRE [19]. Functional neuroimaging modalities like Fluorodeoxyglucose Positron Emission Tomography (FDG-PET) and ictal/interictal Single-Photon Emission Computed Tomography (SPECT) usually shows hypometabolic, hyperperfused regions which extends beyond conventional type of MRI-defined lesions reflecting distributed epileptogenic networks [20,21]. Magnetoencephalography (MEG), high-density EEG can also help further to enhance detection of multifocal or bilateral epileptiform sources usually in MRI-negative epilepsy [19,22]. Collectively all of these findings further support concept of DRE as a disorder having pathological neural networks rather than a focal cortical abnormality alone thereby it reinforces rationale for network-modulating surgical or neuromodulatory interventions [19].

Clinical and Neurodiagnostic Determinants of Awake Craniotomy (AC) in Drug-Resistant Epilepsy (DRE)

Importantly, all of these clinical and neurodiagnostic characteristics provide a strong rationale for considering AC in few selected patients having DRE [23]. The presence of frequent, disabling type of seizures with mixed semiology, early onset often further reflects complex epileptogenic networks which overlaps or lie in close proximity to eloquent cortical regions [23,24]. Structural abnormalities that are observed on MRI such as focal cortical dysplasia, perisylvian lesions, or mesial temporal sclerosis extending towards language or motor cortices raise concerns regarding postoperative neurological morbidity if resection is done under general anaesthesia [25]. AC thereby enables helping real-time cortical, subcortical functional mapping, thus allowing maximal resection of the epileptogenic zone while also preserving essential functions such as language, motor control, cognition, which is usually very important in patients with pre-existing neurological deficits [25,26].

Neurodiagnostic findings play very important role in influencing surgical candidacy for AC. Concordance between semiology, MRI lesions, as well as localisation of EEG further supports into focal surgical approaches, whereas multifocal or bilateral-EEG abnormalities which necessitate precise functional boundary definition than wide resection [27]. Interictal epileptiform discharges which involves dominant hemisphere regions, language networks, sensorimotor cortex justify awake mapping for delineation of functional cortex intraoperatively [27]. Advanced neurophysiological findings which are inclusive of ictal onset patterns, cortical irritability that is detected on scalp or invasive EEG, help identify candidates in whom awake surgery may optimise seizure control while minimising functional compromise [27,28]. All together these neurodiagnostic parameters guide selection of patients, surgical planning, intraoperative strategy, along with establishing AC as a valuable, function-preserving approach in complex patients having DRE [27].

Perioperative Strategies and Anaesthetic Implications in Drug-Resistant Epilepsy (DRE)

The special anaesthetic challenges surrounding DRE epilepsy surgery (temporal lobectomy, lesionectomy, hemispherectomy, corpus callosotomy and similar procedures) are due to the balance between the requirements of safe airway/physiologic control and the demands of accurate neurophysiologic monitoring and prompt neurologic assessment [29]. Cortical epileptiform activity is suppressed by deep planes of anaesthesia, by benzodiazepines which can also blunt intraoperative ECoG or cortical mapping, but on the other hand, epileptiform discharges may be induced by lighter planes or by pharmacologic stimulation, so the anaesthetist must select these drugs and depth to meet the intended monitoring program and phase of surgery [30,31].

Proceed with chronic ASMs during the preoperative period, if the enteral dosage will be discontinued; administer intravenous (i.v.) equivalents (e.g., i.v. levetiracetam, i.v. fosphenytoin) to prevent missed doses and break through seizures [32]. When an oral dosing will be discontinued, consider using the same intravenous formulations (or temporarily replace i.v. agents like levetiracetam, fosphenytoin and fosphenytoin substitutes) since missed doses significantly predispose to breakthrough perioperative seizures [33]. Lastly, protocols and rescue drugs must be available (i.v. benzodiazepines, i.v. ASMs), and the situation in which transient cortical activation would be acceptable to map versus a situation where seizure suppression is desirable for safety of the patient [32,33]. Anaesthetic considerations for epilepsy surgery in DRE are mentioned in [Table/Fig-1].

Role of Awake Craniotomy (AC) in Drug-Resistant Epilepsy (DRE) Surgery

The AC can map functions in real time and ECoG during surgery as it is possible to resect with maximum safety and maintain key neurological functions [34]. Cortical stimulation testing, an important part of the awake procedures, requires the patient to cooperate and is used to delineate functional cortex and find the zones of seizure onset [34]. AC is associated with proper resection of margins, a decreased postoperative neurological deficit, and improves seizure-free outcomes in the targeted patients compared to surgery with the use of general anaesthesia [34,35].

In a case reported by Smith KM et al., a 50-year-old man having drug-resistant left frontal epilepsy underwent awake cortical resection along with language and motor mapping, thereby allowing maximal safe excision of the seizure onset zone which resulted into Engel class I seizure freedom with only transient neurological deficits [34]. Similarly, Bajwa MH et al., reported a 19-year-old woman having right parietotemporal DRE who underwent a neuro-navigation–guided AC, achieving complete resection without any type of functional impairment, sustained seizure freedom at 1-year follow-up [35].

SAS or AAA methods with short-acting agents, including propofol and remifentanil, with local scalp blocks usually result in smooth, well-controlled anaesthetic management [10]. It is important to select and counsel patients preoperatively; potentially reducing feasibility

Risk	Objective	Evaluation	Plan	Rationale	References
Suppression of epileptiform activity due to deep anaesthesia or benzodiazepine use	Maintain optimal anaesthetic depth for reliable neurophysiologic monitoring	Monitor depth of anaesthesia (BIS, EEG trends, haemodynamics); coordinate with neurophysiologist	Avoid excessive anaesthetic depth and benzodiazepines during ECoG or cortical mapping	Deep anaesthesia and benzodiazepines can suppress cortical activity and distort intraoperative ECoG results	[29-31].
Excessive cortical activation or seizures due to light anaesthesia	Prevent intraoperative seizures and ensure patient safety	Continuous EEG/ECoG monitoring	Titrate anaesthetic depth carefully; use anticonvulsant agents if seizures occur	Lighter anaesthesia may provoke epileptiform discharges, increasing intraoperative seizure risk	[30,31].
Interruption of chronic Antiseizure Medications (ASMs)	Maintain steady-state ASM levels and prevent breakthrough seizures	Review perioperative medication history and fasting status	Continue chronic ASMs perioperatively; substitute i.v. equivalents (e.g., i.v. levetiracetam, i.v. fosphenytoin) if enteral dosing is stopped	Missed ASM doses can trigger breakthrough seizures during or after surgery	[32,33].
Lack of rescue plan for intraoperative seizures	Ensure immediate management of breakthrough seizures	Confirm availability of emergency drugs in OR	Keep i.v. benzodiazepines and i.v. ASMs readily available; follow pre-established seizure management protocol	Prompt seizure control minimises neuronal injury and ensures patient safety	[32,33].
Balancing safe airway/ physiologic management with neurophysiologic monitoring needs	Achieve optimal operating conditions while preserving monitoring accuracy	Continuous haemodynamic and neurophysiologic assessment	Use anaesthetic agents compatible with neurophysiologic monitoring (e.g., low-dose volatile, TIVA with propofol/remifentanil)	Certain anaesthetic agents interfere with ECoG/cortical mapping accuracy	[29].

[Table/Fig-1]: Anaesthetic considerations for epilepsy surgery in Drug-Resistant Epilepsy (DRE) [29-33].

by anxiety and lack of cooperation or a language barrier [36]. AC used by a well-trained multidisciplinary team is safe and effective in maximising surgical outcome in DRE without predisposing to more perioperative complications [36].

In a large single-centre retrospective cohort of 558 consecutive ACs, patients having drug-resistant focal epilepsy did not show higher rates of delayed awakening, poor intraoperative cooperation, procedure abandonment, or early postoperative seizures compared with controls [36]. Although a longer duration of uncontrolled seizures was associated to more intraoperative seizures, these were transient and conservatively managed. Importantly, uncontrolled seizures did not interfere with functional mapping as well as extent of resection [36]. Multivariable analysis confirmed that DRE was not linked independently to reduced feasibility, increased perioperative complications, thereby supporting safety of AC when it performed by experienced multidisciplinary teams [36].

Asleep-Awake-Asleep (SAS) versus Awake-Awake-Awake (AAA) Protocols for Awake Craniotomy (AC)

The SAS method entails the initial induction of the patient under general anaesthesia to undergo craniotomy followed by the patient being made awake under cortical mapping as a method to assess critical functional areas and finally being re-sedated to complete tumour resection and closure [10]. This method allows real-time functional evaluation and ensure maximum resection of the tumour with the least risk of developing neurological deficits [37]. It is mostly well-tolerated and the few complications are commonly reported during the awake mapping phase [37]. However, it should be scheduled with anaesthetic caution, as the progressive transition between sedation and wakefulness can be accompanied by the alterations in haemodynamics and the challenges in the control of airways [37].

Otherwise, the AAA protocol keeps the patient awake during the treatment, administering analgesia via scalp nerve blocks or local anaesthesia, and subjected to mild sedation by dexmedetomidine or remifentanil [38]. The benefit of this constant awake method is that it allows a lengthy period of continuous intraoperative monitoring, and more comprehensive functional mapping because the patient is responsive and cooperative at all times [38]. It minimises risks of repeated induction and emergence, but it is not appropriate for patients having high anxiety, low tolerance of long awake procedures, or limited cooperation [38]. Comparison between SAS and AAA techniques in AC is mentioned in [Table/Fig-2].

Parameter	SAS (Asleep-Awake-Asleep) technique	AAA (Awake-Awake-Awake) technique	References
Anaesthetic sequence	Patient is initially induced under general anaesthesia for craniotomy, awakened during cortical mapping, and re-sedated for tumour resection and closure.	Patient remains awake throughout the procedure; analgesia is achieved via scalp nerve blocks or local anaesthesia with mild sedation (dexmedetomidine or remifentanil).	[10,38]
Functional assessment	Allows real-time functional assessment during the awake phase, balancing tumour resection and neurological safety.	Enables continuous intraoperative monitoring and comprehensive functional mapping throughout surgery.	[37,38]
Advantages	- Combines comfort of general anaesthesia with awake mapping benefits. - Minimises discomfort during opening and closure phases. - Well tolerated with minimal complications.	- Continuous patient responsiveness enables prolonged mapping. - Avoids risks of repeated induction and emergence. - Facilitates detailed functional monitoring.	[37,38]
Challenges/ Limitations	- Requires careful anaesthetic planning due to transitions between sedation and wakefulness. - Risk of haemodynamic fluctuations and airway control difficulties.	- Not suitable for highly anxious or uncooperative patients. - Demanding for patients with low tolerance to long awake periods.	[37,38]
Haemodynamic and Airway Considerations	Shifting sedation levels can cause haemodynamic changes and complicate airway management.	Stable haemodynamics but requires vigilance for airway obstruction due to sedation or patient fatigue.	[37,38]
Patient Selection	Suitable for patients who may not tolerate prolonged awake procedures.	Best suited for cooperative, motivated, and psychologically prepared patients.	[38]

[Table/Fig-2]: Comparison between SAS and AAA techniques in Awake Craniotomy (AC) [10,37,38].

Patient Selection and Psychological Preparation for Awake Craniotomy (AC)

Patient selection is crucial to the success of AC [39]. The perfect candidates are those whose tumours are located in functional areas especially when the preoperative imaging indicates the involvement

of critical regions [39]. Also, patients must have sufficient cognitive function, emotional stability, and cooperativeness in intraoperative testing, an activity that usually involves language or motor stimulation tasks [40]. There are contraindications such as serious psychiatric disorders, language or cognitive impairments, and diseases that can affect patient cooperation or safety during the awake state [40]. Psychological preparation is critical to the success of AC [40]. The thorough preoperative psychological evaluation would help to recognise the possible risks and ensures that patients and their families are well-informed and mentally prepared [40]. This is usually accompanied with counselling to overcome fears and anxieties, information of the procedure, and stress management strategies [40]. Adult patients usually depends on the structured counselling, cognitive assessment, as well as reassurance-based strategies to ensure adequate cooperation and emotional stability during awake intraoperative testing [40].

In paediatric population, psychological assessment and intervention are especially crucial, and certain patients may need further intervention to overcome psychological difficulties in the aftermath of surgery [41]. These interventions usually involve exposure to videos of the operating room, hypnosis, multiple encounters with psychologists and speech therapists, and extensive exposure to the operating room theatre [41,42]. These preparatory activities serve to get the child used to the surgical setting, decrease anxiety, and bring about a sense of control and knowledge [41]. In addition, age-appropriate neuropsychological screening, parental involvement during preparatory phase as well as individualised behavioural conditioning protocols have been shown to significantly improve task compliance and intraoperative cooperation in children undergoing AC [41,43]. The role of multidisciplinary teams which is inclusive of child psychologists, paediatric anaesthesiologists, neuro-rehabilitation specialists is important in tailoring preparation strategies according to stage of development, baseline levels of anxiety also cognitive maturity [44]. Structured postoperative psychological follow-up is recommended for addressing emotional distress, behavioural changes, adjustment disorders which can emerge after surgical operation thereby helps supporting long-term neuropsychological well-being of patient [44,45].

Airway Management and Intraoperative Monitoring in Awake Craniotomy (AC)

During AC for DRE, careful airway control and monitoring are important factors in patient safety and surgical effectiveness [46]. The supplemental oxygen is given through nasal cannula and supported by capnography to determine the end-tidal CO_2 levels in order to maintain adequate ventilation during the procedure [46]. Bispectral Index (BIS) monitoring is used to ensure anaesthesia depth and helps to maintain the optimal level of sedation to responsiveness ratio in the patient [47]. Intraoperative blood pressure is used in long surgeries to identify a haemodynamic change as soon as possible [46]. Anaesthetic plan should be flexible enough to provide prompt response to any form of airway obstruction or convulsions, and access to airway intervention equipment and drugs [46].

Anaesthetic and Surgical Risks during Awake Craniotomy (AC) in DRE

The AC in patients having DRE is usually safe when it is performed with careful sedation as well as adequate monitoring, but procedure-specific complications have been well documented. Airway and ventilation-related events are most common which have reported incidences ranging from 1.8% to 18% [48]. Sedative-induced upper airway collapse can result in hypoxia and hypercarbia which is manageable using simple maneuvers such as jaw thrust, supplemental oxygen, or brief mask ventilation [48]. However, some patients having sedative-induced airway collapse may require further advanced airway interventions such as nasopharyngeal airways, laryngeal mask airway placement, CPAP, or even endotracheal intubation, particularly during closure or in cases of severe desaturation [40,48]. Although it is said to be very rare, conversion to general anaesthesia may be necessary due to refractory airway obstruction, profound desaturation, severe agitation, or surgical factors such as brain swelling [49]. Other commonly reported intraoperative complications include seizures which are triggered through cortical stimulation, haemodynamic fluctuations such as hypertension and tachycardia along with nausea, vomiting, or dysphoric reactions, all of which may interfere with patient cooperation and airway safety [50].

In addition to such anaesthesia-related challenges, AC also carries few intrinsic surgical risks. Transient or permanent type of neurological deficits, usually in motor or language function, can occur, especially when operating near eloquent cortex [26,51]. Rare but significant events which are reported in the literature are air embolism, pulmonary aspiration, and respiratory depression from oversedation [49,52]. Psychological stress as well as intraoperative pain can also impact patient tolerance, procedural success [52]. These findings highlight importance of meticulous anaesthetic planning, individualised protocols of sedation, continuous monitoring of oxygenation and end-tidal CO_2, as well as readiness for rapid escalation to airway control, general anaesthesia which helps to ensure patient safety while optimising functional outcomes in patients during AC for DRE [40,52].

Postoperative Management in Awake Craniotomy (AC) for Drug-Resistant Epilepsy (DRE)

Achieving the best results and the low rate of complications after the process of craniotomy is impossible without postoperative care after the AC to treat the DRE. Early neurological and speech assessments are important to detect promptly any deficits caused by the surgery [53]. Such evaluations are usually done during the first 24 hours after surgery and can include standardised tests to measure motor, sensory and cognitive functions, and language skills [53]. Early intervention can be ensured as the deficits can be detected through regular monitoring, which may lead to better results [53]. Another essential element of postoperative care is pain management [54]. To prevent the risk of sedation and cognitive side effects, non-opioid drugs are frequently used to relieve pain, including paracetamol or Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) [54]. Opioids are usually not prescribed unless there is a necessity, as it could impair neurological assessments and predetermine the emergence of complications [54].

It is essential to continue ASMs to avoid the postoperative seizures. Patients in few cases are maintained on their preoperative ASM regimen, with adjustments made based on serum drug levels and renal or hepatic function [53]. Seizure surveillance is required, especially during the immediate postoperative period because the brain is likely more prone to seizure activity after surgery [53]. In other instances, additional ASMs can be used prophylactically in the perioperative phase based on the epileptic history and the outcome of the surgical procedure of a particular patient [53]. Postoperative management strategies following AC for DRE are described in [Table/Fig-3].

Emerging Techniques in Awake Craniotomy (AC) for Drug-Resistant Epilepsy (DRE)

Emerging advances in AC of DRE are improving accuracy, safety, and functional outcomes of surgical procedures. Recent developments of intraoperative monitoring and mapping have helped a great deal in identification and preservation of eloquent regions in the brain [55]. A significant change is utilising high-density circular grid arrays in ECoG [55]. Grids have better spatial resolution than conventional strip electrodes, resulting in higher sensitivity to detecting ictal and interictal activities [55]. Circular grids have been shown to detect periodic focal epileptiform discharges and after-discharges with lower stimulation intensities, which promotes better localisation of epileptic foci [55].

Aspect	Description	Rationale/Goal	References
Neurological and speech assessment	Early assessment within first 24 hours postsurgery to evaluate motor, sensory, cognitive, and language functions using standardised tests.	Enables prompt detection of new neurological or speech deficits for early intervention.	[53]
Regular monitoring	Continuous postoperative monitoring for any evolving neurological or cognitive changes.	Allows early identification and management of complications, improving overall outcomes.	[53]
Pain management	Preferential use of non-opioid analgesics (e.g., paracetamol, NSAIDs). Opioids avoided unless absolutely necessary.	Prevents sedation and cognitive impairment, ensuring reliable postoperative neurological evaluation.	[54]
Antiseizure Medication (ASM) continuation	Maintain preoperative ASM regimen; adjust based on serum levels, renal/hepatic function.	Prevents postoperative seizures and maintains therapeutic drug levels.	[53]
Seizure surveillance	Close observation for seizure activity, particularly in immediate postoperative period.	Brain tissue is more seizure-prone post-surgery; surveillance allows timely management.	[53]
Prophylactic ASM administration	Additional ASMs may be given perioperatively depending on seizure history and intraoperative findings.	Reduces risk of breakthrough or new-onset seizures during recovery.	[53]

[Table/Fig-3]: Postoperative management strategies following Awake Craniotomy (AC) for Drug-Resistant Epilepsy (DRE) [53,54].

There is also functional mapping that has been developed using the RTFM methods [56]. Recently a study proposed a method to examine ECoG signals during natural speech using a technique called Tensor Component Analysis (TCA) which can give a more thorough picture of the cortical mechanisms involved in language [56]. This will result in better mapping accuracy and reduced postoperative deficits [56]. Moreover, neurostimulation technology, including the use of bidirectional CCEP to measure language activity during AC, is undergoing development [57]. CCEP monitoring provides information about language pathways by assessing the connectivity of the areas of the cortex, and it helps preserve vital areas during resection [57].

CONCLUSION(S)

The AC is a crucial step of the surgical therapy of DRE because it offers a compromise of maximality in the reduction of the level of seizures and the preservation of the neurological functions. AC is an effective resection of the epileptogenic foci in personalised protocols and multidisciplinary teamwork using real-time cortical mapping, especially around and within the eloquent cortical structures. The new trends like high density ECoG grids and recent neurostimulations can further can improve the accuracy of intraoperative mapping, minimal postoperative deficits as well as improvement of patient outcome, and thereby, AC seems to form a part of the epilepsy surgery. Meticulous preoperative planning inclusive of patient's psychological preparation and individualised anaesthetic strategies is very essential aspect to maximise safety and surgical success.

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