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IMPROVING ANESTHESIOLOGICAL SUPPORT IN PLANNED RADIOFREQUENCY ABLATIONS

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Abstract. This article is dedicated to the issues of optimizing anesthesiological support during radiofrequency catheter ablation (RFCA) in the condition of atrial fibrillation (AF) – a chronic cardiac rhythm disorder characterized by the emergence of irregular electrical impulses in the atria. AF is electrocardiographically manifested by the absence of P waves, fibrillatory waves, and irregularly irregular R–R intervals, leading to reduced cardiac output and hemodynamic disturbances. The article analyzes the role of sedation depth in improving RFCA outcomes, as sedation controls patient movement, respiratory rhythm, and autonomic responses, thereby determining the quality of the ablation technique. The authors consider sedation not only as a means of patient comfort but as an integrated element of treatment efficacy and safety. The article provides a detailed analysis of the impact of sedation depth on catheter stability, accuracy of electroanatomical mapping, and continuity of lesion formation. In moderate sedation, patient movement and irregular breathing can lead to catheter displacement, which increases the inefficiency of pulmonary vein isolation. Deep sedation or general anesthesia ensures patient immobility but amplifies respiratory (hypoventilation, apnea, hypoxemia) and hemodynamic (vasodilation, bradycardia, hypotension) risks, particularly in patients with obesity, obstructive sleep apnea, or heart failure. The authors emphasize the necessity of individually selecting sedation depth based on the patient's risk profile (e.g., pulmonary reserve, procedure complexity).

Keywords: Atrial fibrillation (AF), radiofrequency catheter ablation, sedation depth, diazepam-fentanyl combination, dexmedetomidine, anesthesiological management, respiratory and hemodynamic safety, clinical outcomes.

Atrial fibrillation (AF) is a chronic cardiac rhythm disorder characterized by the emergence of high-frequency, irregular, and uncoordinated electrical impulses in the atria, resulting in disorganized atrial electrical activity and loss of effective mechanical contraction [15; 18]. In this process, the mechanical activity of the atria becomes ineffective, leading to impaired diastolic filling of the ventricles, reduced cardiac output, and disruption of systemic hemodynamic balance, with these changes

becoming more pronounced in the presence of heart failure or diastolic dysfunction [17; 33]. Electrocardiographically, AF is manifested by the absence of P waves, low-amplitude fibrillatory waves, and irregularly irregular R–R intervals, which serve as the primary diagnostic criteria distinguishing it from other supraventricular arrhythmias [16].

Although the outcomes of radiofrequency catheter ablation in atrial fibrillation depend on multiple factors, sedation depth is one of the most sensitive modifiable factors determining the technical quality of the procedure [16; 21]. In practice, the level of sedation directly shapes the patient's pain perception, movement, respiratory rhythm, and intensity of autonomic responses; this, in turn, affects catheter-endocardial contact, accuracy of electroanatomical mapping, and continuity of lesion formation [5; 14]. Therefore, sedation depth should not be limited to a "comfort" issue but should be viewed as an integrated clinical determinant of ablation efficacy and safety [1; 15].

As sedation deepens, the patient's voluntary and involuntary movements decrease, chest excursion becomes relatively uniform, and pain-related reflex responses are attenuated, which can improve stable contact between the catheter and the atrial wall [3; 21]. In ablation, the quality of contact and its temporal stability are crucial for forming transmural and contiguous lesions, while episodic loss of contact or micro-displacements increase the likelihood of gaps, electrical reconnection points, and unstable pulmonary vein isolation [5; 12]. From this perspective, deep sedation or general anesthesia conditions, by ensuring patient immobility and controllable respiration, can enhance catheter stability, improve mapping accuracy, and support the technical success of the procedure [15; 16]. However, these advantages are not always universal, as in certain patients—particularly those with obesity, obstructive sleep apnea, heart failure, or chronic lung diseases—deep sedation may exacerbate airway collapse or ventilation-perfusion mismatch, increasing the need for additional interventions during the procedure, which in turn disrupts the procedural rhythm and indirectly hinders catheter manipulations [3; 7]. Respiratory and hemodynamic effects are the safety aspects most strongly linked to sedation depth [4; 8]. In moderate sedation, the patient typically breathes independently, but pain and anxiety can cause hyperventilation, irregular breathing, sudden deep inspirations, coughing, or movement, which amplify micro-changes in catheter position through chest movements and negatively impact lesion quality [3; 11]. While deep sedation and general anesthesia allow for more stable respiratory management, these levels carry higher risks of hypoventilation, apnea episodes, hypoxemia, and airway obstruction, especially when opioids or combined sedatives are used [7; 14]. Hemodynamically, as sedation deepens, the risks of vasodilation, myocardial depression, bradycardia, and arterial hypotension increase [6; 13]. In electrophysiologic procedures, such changes, on one hand, increase perfusion reduction and ischemic risk from a patient safety

standpoint, and on the other hand, degrade stable working conditions during mapping and ablation, complicating procedural logistics [1; 10]. Therefore, selecting sedation depth requires finding a clinical balance between gains in catheter stability and the respiratory-hemodynamic "cost," which is decisive [16; 21].

The impact of sedation depth on procedure-related complications is also multifaceted. Inadequate sedation, accompanied by pain and movement, can increase the risk of unexpected catheter displacement, vascular access site trauma, prolonged procedure duration, and sometimes temporary interruption of the procedure [3; 11]. Such situations, in turn, increase radiation exposure, resource consumption, and the likelihood of repeat manipulations [2; 5]. Deep sedation or general anesthesia, while reducing the movement component, is associated with its own specific complication profile: hypoxemia, aspiration risk, difficulties in airway management, drug-related bradycardia and hypotension, prolonged post-procedural recovery, and increased costs in some centers [7; 14]. A frequently encountered practical problem is that if the sedation level proves insufficient or, conversely, unpleasant respiratory or hemodynamic reactions occur, it becomes necessary to change the sedation strategy or convert to general anesthesia during the procedure, which prolongs the procedure duration and increases demands on team coordination [15; 16].

At the same time, the literature emphasizes the ambiguity of the relationship between sedation depth and long-term clinical outcomes, including recurrence and the need for repeat ablation [14; 16]. Some analyses suggest that under deep sedation or general anesthesia, technical outcomes may be more positive due to improved catheter stability and lesion quality [5; 15], while other sources note that clinical superiority is not always consistently manifested due to differences in patient selection, center experience, applied technique, and protocols [13; 14]. Therefore, the selection of sedation depth should not follow simplified rules such as "deepest is best" or "lightest is safest," but should be individually determined based on the patient's risk profile—specifically obstructive sleep apnea, obesity, heart failure, and pulmonary reserve—the procedure's complexity, including paroxysmal and persistent atrial fibrillation, anticipated procedure duration and lesion volume, as well as the center's capabilities for anesthesiological monitoring and airway management [3; 7]. It is these clinical subtleties that intensify the need for scientifically based comparative evaluation of sedation strategies and the development of optimal protocols in atrial fibrillation ablation [16; 21]. In electrophysiologic and interventional cardiology practices, effective pain control, reduction of patient anxiety, and ensuring immobility during the procedure are central components of the sedation strategy [1; 10]. In practice, these goals are achieved through various drug combinations, and one of the most common classic approaches is the joint use of benzodiazepines and opioid analgesics [26; 34]. The diazepam-fentanyl combination has long been used in many centers as

neuroleptanalgesia or combined sedoanalgesia, aimed at providing simultaneous sedation, anxiolysis, and analgesia [1; 23].

Diazepam belongs to the benzodiazepine group and enhances inhibitory effects in the central nervous system via GABA-A receptors [12; 28]. Its primary mechanism is associated with increasing the opening frequency of GABA-mediated chloride channels, resulting in decreased neuronal excitability and sedative and anxiolytic effects [25; 26]. In clinical practice, diazepam's sedative and anxiolytic properties are particularly important, as it reduces psychoemotional tension in the patient, attenuates fear and autonomic stress reactions associated with the procedure, and also has muscle relaxant and anticonvulsant effects [1; 11]. Another clinically significant feature of diazepam is its tendency to enhance anterograde amnesia, which can improve subjective tolerance to the procedure in some patients [26; 33].

However, diazepam also has limitations. Its pharmacokinetic profile, particularly high lipophilicity, leads to rapid tissue distribution and the presence of active metabolites, which can prolong the duration of sedation and intensify post-procedural drowsiness and cognitive slowdown [7; 17]. The risk of accumulation increases in the elderly, patients with reduced liver function, or those taking multiple medications [8; 26]. Additionally, benzodiazepines can suppress the respiratory center with dose increases, although this effect is generally less pronounced compared to opioids; however, in combination with opioids, the risk of respiratory depression sharply increases [7; 14]. Paradoxical reactions, including restlessness and agitation, may be observed in some patients, complicating clinical management [26; 31]. Furthermore, diazepam's sedative profile is not always optimal from a dose titration perspective, as fine control of depth after effect onset can be challenging in some cases [1; 35].

Fentanyl is a potent synthetic opioid analgesic that primarily acts as a μ-opioid receptor agonist [23; 25]. It attenuates central processing of pain impulses, reduces pain response reactions, and increases tolerance to nociceptive stimuli occurring during the procedure [26; 32]. One of the key advantages of fentanyl in interventional procedures is its rapid onset and short to moderate duration of action, allowing for titration adapted to the procedural process [7; 16]. During painful manipulations such as radiofrequency ablation, fentanyl can reduce the patient's pain perception, attenuate sympathetic responses, and thereby decrease pain-related fluctuations in heart rate and arterial pressure [1; 10].

At the same time, fentanyl's most significant clinical risk is associated with suppression of the respiratory center and induction of ventilation disturbances, as opioids with dose increases significantly elevate the risk of hypoventilation, apnea episodes, and hypoxemia—particularly becoming clinically more significant in patients with obesity, obstructive sleep apnea, chronic lung disease, or heart failure [7; 14]. Fentanyl can also cause rare but potentially dangerous adverse reactions such as

chest wall rigidity, which complicates ventilation and increases the likelihood of requiring rapid airway management [18; 23]. From a cardiovascular perspective, although fentanyl is generally considered a relatively hemodynamically stable drug, it can increase vagal tone, thereby enhancing the propensity for bradycardia, and in combination with other sedatives, it may amplify arterial pressure reduction [1; 10]. In this regard, when using the diazepam-fentanyl combination, it is important to assess sedation quality and perform stepwise dose titration, conduct continuous monitoring of respiration and hemodynamics, and work in an environment equipped for rapid reversal and airway management if necessary [3; 7]. It is these precautions that serve to minimize the respiratory and hemodynamic risks of the combination while preserving its clinical benefits [10; 26]. At the same time, as modern electrophysiologic practices increasingly orient sedation strategies toward predictable profiles, titratable depth, and minimal respiratory depression principles, the diazepam-fentanyl approach is regarded in many centers as a classic variant comparable to alternative regimens [16; 21].

In recent years, dexmedetomidine has garnered particular interest in the direction of improving sedation strategies in electrophysiologic and interventional cardiology practices, as this drug, due to its unique pharmacodynamic properties, has elevated the concept of analgosedation to a new level and has begun to be widely used in prolonged and high-precision procedures such as radiofrequency catheter ablation [14; 16]. Dexmedetomidine combines sedative and analgesic effects, allowing for increased patient comfort, maintenance of hemodynamic stability, and support of procedural technical efficacy [1; 4].

Dexmedetomidine is a selective alpha-2 adrenoreceptor agonist, with its primary mechanism of action involving activation of presynaptic alpha-2 receptors in the central nervous system, thereby reducing norepinephrine release, leading to decreased sympathetic nervous system activity and the emergence of sedative and anxiolytic effects [4; 17]. This type of sedation is characterized by a state resembling physiological sleep, preserving the patient's arousability and ability to respond to commands, which is important for balancing functional monitoring in electrophysiologic procedures [3; 9].

One of the main advantages of dexmedetomidine in cardiologic and electrophysiologic procedures is its minimal respiratory depression, as the drug does not significantly suppress the respiratory center, and independent breathing is maintained in most patients [3; 14]. This condition reduces respiratory risks in prolonged procedures like radiofrequency catheter ablation and limits the need for aggressive airway management [7; 16]. At the same time, sedation provided by dexmedetomidine is often described as cooperative sedation, meaning the patient remains calm but can establish short-term communication when necessary, which represents an important clinical advantage in certain electrophysiologic assessment

stages [1; 9]. However, the use of dexmedetomidine is also associated with certain adverse effects, with the most common undesirable conditions being bradycardia and arterial hypotension, explained by the drug's sympatholytic effect [7; 14]. These hemodynamic changes are often dose- and infusion rate-dependent and may become more pronounced with initial loading doses or high infusion rates [4; 23]. In some patients, particularly those with impaired cardiac conduction, taking beta-blockers, or with heart failure, bradycardia may reach clinically significant levels [6; 11].

Due to dose-dependent hemodynamic changes, individual titration and continuous monitoring are important when using dexmedetomidine [3; 7]. Slow and cautious infusion of the drug, avoidance or minimization of loading doses, can reduce the risk of adverse effects [4; 14]. Under these conditions, dexmedetomidine-based analgosedation is regarded as a modern approach that provides an optimal balance between patient comfort, respiratory safety, and hemodynamic stability in electrophysiologic procedures, allowing it to be evaluated as a promising alternative to classic benzodiazepine-opioid combinations [1; 16].

Pain control holds special importance in the comparative evaluation of sedation strategies [14; 26]. During radiofrequency ablation, pain intensity varies across different stages of the procedure and plays a significant role in the patient's subjective experience [21; 33]. Special scales are used to assess pain, which help determine the effectiveness of sedation and analgesia [3; 26]. Strategies with sufficient analgesic effect are characterized by low pain scores and less patient discomfort during the procedure [5; 16]. Conversely, in cases of inadequate analgesia, the need arises for additional or rescue analgesics, which can lead to an unexpected increase in sedation depth and heightened respiratory risks [7; 14]. Therefore, the need for rescue analgesia is considered an important indirect criterion indicating the adequacy of the sedation strategy [3; 26].

The safety profile and complications of sedation strategies hold significant importance in evaluating radiofrequency ablation outcomes, with respiratory depression being one of the complications requiring the most attention [1; 3]. Suppression of breathing, hypoxemia, or apnea episodes occur depending on sedation depth and the drug combinations used, potentially requiring additional interventions during the procedure and disrupting procedural rhythm [7; 14]. These sedation-related issues in some cases force temporary interruption of the procedure or changes to the sedation strategy, which prolongs the overall duration of radiofrequency ablation and increases technical complexity [9; 10]. Although the number of literature sources dedicated to sedation and analgesia issues during radiofrequency catheter ablation in atrial fibrillation has significantly increased in recent years, several important methodological and practical limitations persist in this direction [16; 21]. One of the main problems is the high heterogeneity of sedation protocols, with different studies

using drugs, their doses, administration methods, and sedation depths that differ significantly from each other [14; 26]. Some works analyze approaches based on moderate sedation, while others evaluate deep sedation or general anesthesia, making direct comparison of results difficult [12; 13]. Additionally, many studies do not use unified standardized indicators for evaluating outcomes related to sedation and analgesia [3; 26]. Criteria such as patient comfort, pain intensity, sedation quality, hemodynamic stability, and post-procedural recovery are measured through various scales or subjective assessment methods, complicating the identification of clinically significant differences and their transformation into generalized conclusions [1; 9]. Most works have a retrospective design, remaining open to selection biases and the influence of confounding factors [14; 16]. Despite existing evidence, the issue of determining the optimal sedation regimen for radiofrequency ablation remains open [16; 21]. In practice, different centers select sedation strategies based on their experience and resources, but there is no unified consensus on which pharmacologic approach is most acceptable for patients [1; 10]. In particular, the optimal choice between benzodiazepine and opioid combinations, alpha-2 adrenoreceptor agonist-based analgosedation, and general anesthesia can vary sharply depending on the clinical situation [7; 14].

From a practical standpoint, the results of this study can support the clinical decision-making process in selecting sedation strategies during electrophysiologic procedures. Conclusions based on clear evidence help increase patient safety, reduce procedure duration and complication risks, and promote efficient resource utilization. At the same time, the study results create a scientific basis for improving clinical protocols on anesthesiological management during radiofrequency ablation and adapting them to local practice. As a result, optimizing sedation and analgesia approaches in the invasive treatment of atrial fibrillation creates the opportunity to provide a safer and more effective clinical environment for patients

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