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Research Article

Comparison of nicardipine and esmolol for intraoperative blood pressure control during awake deep brain stimulation surgery: a retrospective study

Uyanık derin beyin stimülasyonu ameliyatında intraoperatif kan basıncı kontrolü için nikardipin ve esmololün karşılaştırılması: retrospektif bir çalışma

Esra Turunc*, Burhan Dost, Yasemin Burcu Ustun, Cengiz Kaya, Sezgin Bilgin, Ersin Koksal, Bahriye Binnur Sarıhasan

Department of Anesthesiology and Reanimation, Ondokuz Mayis University Faculty of Medicine, Samsun, Turkey

Abstract

Aim: Awake deep brain stimulation (DBS) surgery requires the patient to remain conscious for optimal electrode placement through intraoperative neurophysiological monitoring. However, hypertension during awake DBS poses significant clinical challenges, potentially compromising surgical accuracy and patient safety. Nicardipine and esmolol are both used for intraoperative blood pressure control, but their comparative efficacy in awake DBS remains unclear. The aim of this study was to compare the effectiveness of nicardipine and esmolol in controlling intraoperative blood pressure during awake DBS surgery under monitored anesthesia care.

Material and Methods: This retrospective study evaluated patients who underwent awake DBS surgery under MAC between January 2020 and April 2025. Forty adult patients experiencing intraoperative hypertension (systolic arterial pressure [SAP] ≥150 mmHg) were included and divided into two groups based on the antihypertensive agent administered: nicardipine (n = 20) or esmolol (n = 20). Hemodynamic parameters, antihypertensive requirements, and intraoperative complications were compared between the groups.

Results: Mean intraoperative SAP was significantly lower in the nicardipine group compared to the esmolol group (121.9 ± 2.6 mmHg vs. 127.9 ± 3.5 mmHg, p = 0.04). Although the frequency of hypertensive episodes tended to be lower with nicardipine, this did not reach statistical significance (15.9% ± 3.6 vs. 26.1% ± 4.1, p = 0.21). Esmolol resulted in significantly lower heart rates (69.2 ± 2.8 bpm vs. 87.9 ± 2.0 bpm, p = 0.01) but required higher doses of rescue antihypertensives (glyceryl trinitrate: 53.1 ± 5.8 mg vs. 25.8 ± 1.2 mg, p < 0.001). No major intraoperative complications or conversions to general anesthesia occurred in both groups.

Conclusions: Nicardipine provided more effective and stable intraoperative blood pressure control than esmolol during awake DBS surgery, reducing the need for additional antihypertensive medications. Both agents were safely administered without compromising patient cooperation or neurophysiological monitoring. Therefore, nicardipine may be preferable due to the less need for rescue antihypertensive treatment.

Keywords: awake deep brain stimulation, hypertension, nicardipine, esmolol, intraoperative hemodynamics, neuroanesthesia

Corresponding Author*: Esra Turunç Ondokuz Mayis University, School of Medicine, Department of Anesthesiology, Kurupelit, Samsun, Turkey
E-mail: esra.kiymaz.ek@gmail.com
Orcid: 0000-0003-0159-7403
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Öz

Amaç: Uyanık derin beyin stimülasyonu (DBS) cerrahisi, elektrotların optimal yerleştirilmesi için hastanın bilinçli kalmasını ve intraoperatif nörofizyolojik monitörizasyona olanak tanınmasını gerektirir. Ancak, cerrahi sırasında gelişen hipertansiyon önemli klinik zorluklara neden olabilir; bu durum cerrahi doğruluğu ve hasta güvenliğini tehlikeye atabilir. İntraoperatif kan basıncı kontrolü için nikardipin ve esmolol sıklıkla kullanılmaktadır, ancak uyanık DBS cerrahisinde bu ilaçların karşılaştırmalı etkinliği net değildir. Bu çalışmanın amacı, monitörize anestezi bakımı (MAB) altında uyanık DBS cerrahisi sırasında intraoperatif kan basıncını kontrol etmede nikardipin ve esmololün etkinliğini karşılaştırmaktır.

Gereç ve Yöntemler: Bu retrospektif çalışmada, Ocak 2020 ile Nisan 2025 tarihleri arasında MAB altında uyanık DBS cerrahisi geçiren hastalar değerlendirildi. İntraoperatif hipertansiyon (sistolik arter basıncı [SAP] ≥150 mmHg) gelişen 40 erişkin hasta çalışmaya dahil edildi ve uygulanan antihipertansif ajana göre iki gruba ayrıldı: nikardipin (n = 20) ve esmolol (n = 20). Hemodinamik parametreler, antihipertansif gereksinimler ve intraoperatif komplikasyonlar karşılaştırıldı.

Bulgular: İntraoperatif ortalama SAP, nikardipin grubunda esmolol grubuna göre anlamlı şekilde daha düşüktü (121,9 ± 2,6 mmHg vs. 127,9 ± 3,5 mmHg, p = 0,04). Hipertansif atak sıklığı nikardipin grubunda daha düşük olmasına rağmen istatistiksel olarak anlamlı değildi (15,9% ± 3,6 vs. 26,1% ± 4,1, p = 0,21). Esmolol, anlamlı şekilde daha düşük kalp hızına neden oldu (69,2 ± 2,8 atım/dk vs. 87,9 ± 2,0 atım/dk, p = 0,01), ancak daha yüksek dozda kurtarıcı antihipertansif (gliseril trinitrat: 53,1 ± 5,8 mg vs. 25,8 ± 1,2 mg, p < 0,001) gereksinimi oldu. Her iki grupta da büyük intraoperatif komplikasyon veya genel anesteziye geçiş gözlenmedi.

Sonuç: Uyanık DBS cerrahisinde, nikardipin esmollole kıyasla daha etkili ve stabil bir intraoperatif kan basıncı kontrolü sağlamış ve ek antihipertansif ilaç ihtiyacını azaltmıştır. Her iki ajan da hasta iş birliğini veya nörofizyolojik monitörizasyonu bozacak bir yan etki göstermeksizin güvenle uygulanabilmiştir. Bu nedenle, ek antihipertansif tedavi gereksiniminin daha az olması nedeniyle nikardipin tercih edilebilir.

Anahtar Kelimeler: uyanık derin beyin stimülasyonu, hipertansiyon, nikardipin, esmollol, intraoperatif hemodinami, nöroanestezi

Introduction

C Awake deep brain stimulation (DBS) surgery is frequently preferred for the treatment of advanced Parkinson's disease and certain movement disorders [1]. In this technique, the patient remains awake, allowing real-time assessment of motor and speech functions during the placement of electrodes in the targeted brain regions. However, the patient's conscious state requires careful coordination between the surgical and anesthesia teams. Maintaining intraoperative hemodynamic stability is of critical importance, as fluctuations in blood pressure may increase the risk of surgical failure and compromise patient safety [2].

To ensure both patient comfort and cooperation during neurophysiological testing, monitored anesthesia care, combining light sedation and local anesthesia, is commonly employed in awake DBS procedures [3,4]. Despite this approach, intraoperative hypertension remains one of the most frequently encountered clinical challenges. It can be triggered by anxiety, surgical stimuli (e.g., head fixation, burr hole drilling), or the psychological stress of remaining awake. Uncontrolled hypertension may lead to increased intracranial pressure, impaired cerebral perfusion, and an elevated risk of cerebral edema or hemorrhage [5]. Conversely, overly aggressive antihypertensive treatment may result in hypotension and cerebral hypoperfusion. Therefore, achieving effective and safe blood pressure control throughout the procedure is essential.

An ideal antihypertensive agent should have a rapid onset and offset of action, allowing easy titration to the target blood pressure and quick discontinuation once the triggering stimulus has resolved. Nicardipine is a commonly used antihypertensive in neurosurgical and neurocritical care patients and demonstrates a rapid onset when administered via infusion. However, its effects may persist for 4 to 6 hours even after discontinuation of prolonged infusions [6]. In contrast, esmolol has a similarly rapid onset but is metabolized quickly by red blood cell esterases, resulting in an offset of action within less than 30 minutes after discontinuation. Esmolol primarily acts by reducing heart rate and myocardial contractility, and therefore, its maximal blood pressure-lowering effect may be more limited compared to agents like nicardipine that provide direct arterial vasodilation [7]. Nevertheless, studies directly comparing the efficacy of these two agents in controlling blood pressure during awake DBS surgery are scarce in the literature. In this retrospective study, we aimed to compare the hemodynamic effects and clinical outcomes of nicardipine and esmolol for intraoperative blood pressure management in patients undergoing awake deep brain stimulation surgery under monitored anesthesia care (MAC) at our institution.

Materials and Methods

Study Design

This retrospective observational study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [8]. Ethical approval was obtained from the local ethics committee of Ondokuz Mayıs University (Decision No: 2025/91, dated April 15, 2025). The data of patients who underwent awake DBS surgery between January 2020 and April 2025 were retrieved from the Hospital Medical Information System and anesthesia records. The study was carried out in accordance with the principles of the Declaration of Helsinki (64th WMA General Assembly, Fortaleza, Brazil, October 2013).

Participants

This study included patients aged 18 years and older who underwent awake DBS surgery between January 2020 and April 2025. Patients were eligible for inclusion if they developed intraoperative hypertension—defined as systolic arterial pressure (SAP) ≥150 mmHg—during the procedure and received either intravenous nicardipine or esmolol for blood pressure control. Additional inclusion criteria were the use of invasive arterial blood pressure monitoring and the availability of complete anesthesia and hemodynamic records. Patients were excluded if the DBS procedure was performed under general anesthesia, if invasive monitoring was not applied, or if essential perioperative data were missing. Other exclusion criteria included the presence of significant cardiac, hepatic, or renal dysfunction, the need for intraoperative mechanical ventilation or deep sedation, and known allergies to the antihypertensive agents used. A total of 40 patients met the inclusion criteria and were divided into two equal groups based on the antihypertensive agent administered: 20 patients who received nicardipine (Group Nicardipine) and 20 who received esmolol (Group Esmolol). Patient records were reviewed and sorted in descending order by surgical protocol number, and the most recent 20 cases in each group were included in the final analysis to ensure uniformity in documentation and case distribution.

Anesthesia Management

All patients were instructed to fast for 6 hours and refrain from fluid intake for 2 hours prior to surgery. Routine preoperative premedication was not administered. During the initial stage of DBS Surgery- burr hole placement- MAC was provided to all patients. Consciousness was preserved throughout the procedure, and minimal sedation was maintained using low-dose remifentanil (0.01–0.03 mcg/kg/min) when necessary. Infusions were discontinued approximately 30 minutes before neurophysiological testing and resumed after the completion of test procedures.

In addition to standard American Society of Anesthesiologists (ASA) monitoring (electrocardiogram and pulse oximetry), invasive arterial blood pressure monitoring via the radial artery was performed in all patients. Oxygen was delivered via nasal cannula at a flow rate of 2–4 L/min. During episodes of hemodynamic fluctuation, intravenous nicardipine or esmolol was administered in bolus and/or infusion form. When hypertensive episodes (SAP ≥150 mmHg) occurred, the initial intervention was guided by the preferred antihypertensive agent. Glyceryl trinitrate (GTN) was administered as rescue therapy when needed.

During the battery implantation phase, all patients underwent general anesthesia with tracheal intubation. Anesthesia induction was achieved using remifentanil, propofol, and rocuronium. Maintenance of anesthesia was achieved with volatile agents (desflurane or sevoflurane), supplemented with opioids as needed. At the end of surgery, neuromuscular blockade was reversed with neostigmine and glycopyrrolate, and tracheal extubation was performed after confirming full consciousness and a train-of-four ratio demonstrating four responses. All patients were subsequently transferred to the post-anesthesia care unit for further monitoring.

In cases of hypotension (mean arterial pressure (MAP) < 65 mmHg), fluid replacement and titration of anesthetic or antihypertensive agents were performed. For bradycardia (heart rate (HR) < 50 bpm), atropine administration was included in the protocol.

Data Collection

Relevant data were extracted from electronic patient records and anesthesia charts. Demographic information included age, sex, primary diagnosis, ASA physical status classification, presence of comorbidities, and documented history of hypertension. Intraoperative vital parameters—such as SAP, MAP, and HR—were recorded at five-minute intervals throughout the procedure. Details of the antihypertensive agent used, including the type of drug (nicardipine or esmolol), timing of administration, total dose delivered, and duration of infusion, were also documented. The need for additional medications, such as GTN for resistant hypertension or atropine for bradycardia, was noted. Furthermore, total surgical duration and intraoperative complications, such as bradycardia , hypotension, difficulties in electrode placement, or patient movement during critical surgical stages were systematically reviewed and recorded.

Surgical Technique

All surgical procedures were performed by an experienced functional neurosurgery team specialized in stereotactic techniques. Prior to the procedure, a Riechert-Mundinger stereotactic frame was fixed to the patient's skull to facilitate precise targeting. Stereotactic planning was conducted using fusion imaging of contrast-enhanced cranial computed tomography (CT) and magnetic resonance imaging (MRI) scans. Following burr-hole trepanation, microelectrode recordings and intraoperative clinical test stimulation were employed to confirm the optimal target location. After verification, the final electrode was implanted, and correct positioning was confirmed through postoperative imaging of the operative field.

Hypertension was defined as a SAP ≥150 mmHg sustained for at least 3 minutes. Hypotension was defined as a MAP <65 mmHg, and bradycardia as a HR <50 bpm. The need for rescue antihypertensive treatment was determined based on the persistence of elevated blood pressure despite primary agent infusion.

Outcomes

The primary outcome of the study was the intraoperative SAP and the frequency of hypertensive episodes (SAP ≥150 mmHg). Secondary outcomes included intraoperative HR, total dose and duration of antihypertensive agent used, additional drug requirements (e.g., GTN, atropine), and the incidence of intraoperative complications such as bradycardia, hypotension, patient movement, or electrode placement difficulty.

Statistical Analysis

All statistical analyses were performed using SPSS software (version 27). Continuous variables were presented as mean ± standard deviation or median (interquartile range), as appropriate. Categorical variables were expressed as frequencies and percentages (%). Comparisons between the two groups were made using the independent samples t-test or the Mann–Whitney U test for continuous variables. The chi-square test or Fisher's exact test was used for categorical variables. A p-value < 0.05 was considered as statistically significant.

Results

A total of 65 patients were retrospectively evaluated for eligibility for awake DBS surgery. Twenty-five patients were excluded from the study: 9 due to morbid obesity, 7 with a history of drug allergy, 5 with a previous craniotomy, and 4 due to hemodynamic instability. As a result, data from the remaining 40 patients were included in the final analysis, with 20 patients in each group (Figure 1).

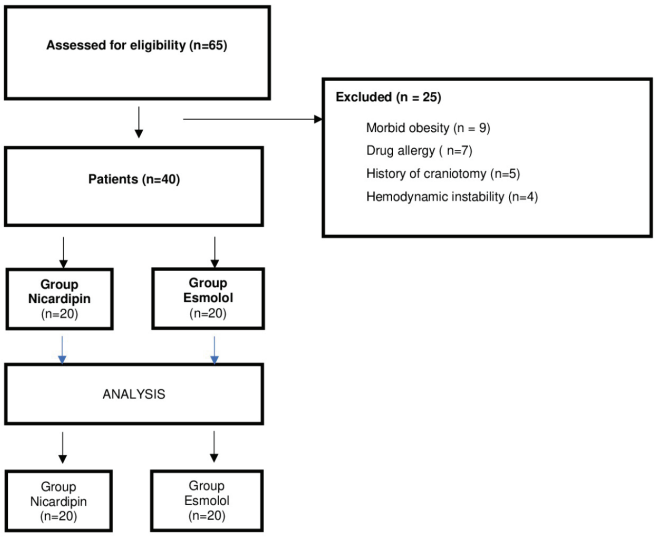

Figure 1. Flow diagram.

Demographic characteristics, including age, sex, ASA classification, and comorbidities, were similar between the two groups, (p > 0.05) (Table 1). Baseline SAP and HR prior to antihypertensive intervention were also comparable between the groups (Table 2).

Mean intraoperative SAP was significantly lower in the nicardipine group compared to the esmolol group (121.9 ± 2.6 mmHg vs. 127.9 ± 3.5 mmHg; p = 0.04). The frequency of hypertensive episodes (SAP ≥150 mmHg) tended to be lower in the nicardipine group (15.9% ± 3.6) than in the esmolol group (26.1% ± 4.1), although this difference did not reach statistical significance (p = 0.21) (Table 2). Nonetheless, this difference may still be clinically relevant. In contrast, the mean intraoperative HR was significantly lower in the esmolol group (69.2 ± 2.8 bpm) than in the nicardipine group (87.9 ± 2.0 bpm; p = 0.01). Patients in the esmolol group required significantly higher doses of rescue antihypertensive medication than those in the nicardipine group (53.1 ± 5.8 mg vs. 25.8 ± 1.2 mg; p < 0.001) (Table 2) (Figure 2).

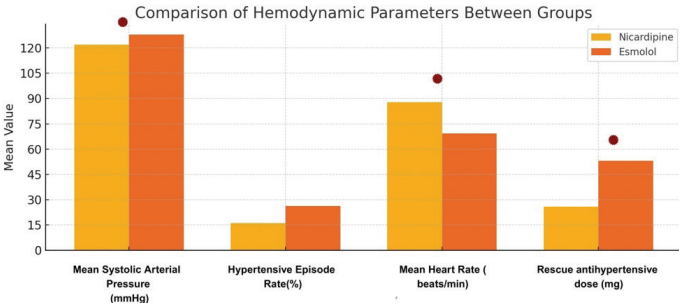

Figure 2. Comparison of hemodynamic parameters between groups.

Table 1. Baseline demographic and clinical characteristics of the nicardipine and esmolol groups.

	Group nicardipine (n=20)	Group esmolol (n=20)	P value
Age (years)	56.0 (37.5-63.0)	55.0 (44.2-59.0)	0.914m
Sex (n, %)			
Female	6(30)	7(35)	0.736X^2
Male	14(70)	(65)	
BMI (kg/ m2)	27.6 ± 4.8 (25.7-29.3)	26.6 ± 3.4 (25.3-27.9)	0.561m
ASA grade (n, %)			
II	16(80)	14(70)	0.633X^2
III	4(20)	6(30)	
Comorbidities (n, %)			
Respiratory system*	2 (10)	3 (15)	0.736X^2
Cardiovascular system†	3 (15)	2 (10)	
Endocrine system‡	4 (20)	2 (10)	
>1 systemic disease	6 (30)	6 (30)	
Operation time (min)	215.0 [100.0 – 300.0]	203.0[110.0 – 265.0]	0.967m
DBS etiology (n, %)			
Parkinson's disease	14(70)	15(75)	0.581 X^2
Huntington's Chorea	3(15)	2(10)	
Tourette Syndrome	1 (5)	0(0)	
Essential Tremor	2 (10)	3(15)	

Abbrev.: BMI: Body mass index, ASA: American Society of Anesthesiologists, Respiratory system*: Asthma, Cardiovascular†: Hypertension, Coronary arterial disease, Endocrine‡: Type 2 diabetes, hypothyroidism.
X^2 Chi-Square test/mMann-Whitney U test. Data are presented as median [Q1-Q3], number of patients (n), and percentage (%). A statistically significant difference is in bold, p <0.05.

Table 2. Baseline and intraoperative hemodynamic parameters and rescue antihypertensive requirements in the nicardipine and esmolol groups.

	Group nicardipine (n=20)	Group esmolol (n=20)	P value
Baseline SAP (mmHg)	131.2 ± 6.1	130.7 ± 5.8	0.72
Baseline DAP (mmHg)	78.4 ± 4.5 (65-95)	77.9 ± 4.3 (66-101)	0.64
Baseline MAP (mmHg)	95.6 ± 4.8 (82-112)	94.6 ± 4.6 (83-110)	0.58
Baseline HR (bpm)	78.4 ± 4.5 (60-86)	74.1 ± 5.7 (62-85)	0.49
Mean SAP (mmHg)	121.9 ± 2.6	127.9 ± 3.5	0.04
Mean HR (bpm)	87.9 ± 2.0	69.2 ± 2.8	0.01
Rescue antihypertensive dose (mg)	25.8 ± 1.2	53.1 ± 5.8	< 0.001
Hypertensive episode rate(%)	15.9± 3.6	26.1 ± 4.1	0.21

Abbrev.: SAP: Systolic Arterial Pressure; DAP: Diastolic Arterial Pressure; MAP: Mean Arterial Pressure; HR: Heart Rate; bpm: beats per minute. Continuous variables were presented as mean ± standard deviation (SD) and range. A statistically significant difference is in bold, p <0.05.

There were no statistically significant differences between the groups regarding intraoperative complications such as hypotension (MAP <65 mmHg), bradycardia (HR <50 bpm), or difficulties in electrode placement due to patient movement. No patient required conversion to general anesthesia, and in no case was electrode implantation interrupted or altered due to hemodynamic instability.

Discussion

In the present study, comparison of nicardipine and esmolol—used for the management of intraoperative hypertension during awake DBS surgery—demonstrated that the nicardipine group achieved more stable control within the target blood pressure range and prevented hypertensive surges more effectively.

Maintaining hemodynamic stability during DBS surgery is critically important for perioperative safety. A comprehensive single-center study spanning ten years reported that patients undergoing DBS experienced an average of 10.8 episodes of intraoperative hemodynamic fluctuations, with a wide range from 0 to 42 episodes per patient [9]. In that study, the term "episode" was defined as any deviation in blood pressure

or heart rate from predetermined target ranges, most of which required pharmacologic intervention. Furthermore, 57% of cases had fluctuations severe enough to necessitate treatment. The analysis also showed that patients with high-normal preoperative blood pressure values had a significantly increased risk of intraoperative hemodynamic instability. These findings highlight the importance of preoperative hemodynamic optimization, particularly in patients with a history of hypertension or autonomic dysfunction.

Although the current literature provides various data on the frequency and management of hemodynamic fluctuations, comparative studies evaluating the intraoperative efficacy of specific antihypertensive agents remain limited. In randomized controlled trials investigating the management of postcraniotomy hypertension, nicardipine has emerged as a more effective agent than esmolol. In the study by Bebawy et al., the failure rate of nicardipine for controlling postoperative hypertension was 5%, compared to 55% with esmolol—indicating that more than half of the patients receiving esmolol required additional rescue medication due to inadequate blood pressure control. The authors concluded that "if a single agent is to be used, nicardipine would be more effective; if esmolol is chosen, a secondary antihypertensive should commonly be an issue." Furthermore, the study reported that time to achieve target blood pressure was significantly shorter in the nicardipine group, and the need for rescue therapy was substantially lower [10].

Accordingly, nicardipine may be considered the first-line agent for intraoperative management of severe hypertensive episodes, while esmolol may be more suitable in cases involving mild hypertension accompanied by tachycardia, or in combination regimens. Similar findings have been reported in cranial surgeries, where nicardipine has demonstrated reliable and rapid control of blood pressure, whereas esmolol exerts its antihypertensive effect primarily through heart rate reduction [11]. In our study, nicardipine was associated with a significantly lower intraoperative mean SAP and a clinically lower frequency of hypertensive episodes. Additionally, the markedly higher requirement for rescue antihypertensives in the esmolol group suggests that beta-blockers may not provide sufficient arterial vasodilation when used as monotherapy. Nevertheless, the significantly lower heart rate observed in the esmolol group reflects its beta-blocker effect and is consistent with previous literature [12].

In the context of awake DBS, maintaining patient cooperation and procedural stability during electrode implantation is essential. Our findings indicate that, when properly titrated, both agents did not negatively affect intraoperative neurophysiological monitoring. Unlike previous studies, our investigation was conducted in an awake surgical setting and further supports the safety of nicardipine in such procedures. Pain, discomfort, increased brain pulsatility, head movement, or poor patient tolerance may all impair MER (microelectrode recording) quality. With well-controlled antihypertensive management, patients remain more relaxed and still, thereby reducing signal artifacts. Nicardipine is particularly useful in this regard, especially in sedation protocols that include ketamine, as it can counteract the hypertensive effects of ketamine and help maintain continuous MER signal acquisition [13]. A case series reported that in an anesthetic protocol combining ketamine, dexmedetomidine, and remifentanil- along with nicardipine- MER quality was preserved in all patients, and optimal targeting was achieved [14].

Intracranial hemorrhage is one of the most serious complications associated with DBS surgery, with reported incidence ranging between 0.5% and 5%, potentially leading to permanent neurological deficits or death [15,16]. Hypertensive episodes during electrode placement and nucleus stimulation have been identified as critical periods during which the risk of bleeding is increased [17]. Although no intracranial complications were observed in our study, marked hypertensive episodes were recorded during these stages. This finding aligns with previous reports indicating that stimulation of structures such as the periaqueductal gray matter or subthalamic nucleus can provoke autonomic cardiovascular responses [18,19]. Similarly, hypotension and bradycardia were more frequently observed during battery placement in our cohort, which may be attributed to the effects of general anesthesia and underlying autonomic dysfunction, as described in the literature. Nevertheless, no serious hemodynamic complications occurred during the generator implantation phase. Our findings suggest that predictable hemodynamic changes may arise depending on the surgical phase of DBS, and with appropriate anesthetic management, these changes can be safely controlled.

This study has several important limitations. First, the retrospective design may have introduced unmeasured biases related to patient selection, treatment decisions, and data recording processes. Second, a formal sample size calculation was not performed; instead, the final cohort included the most recent 20 eligible patients in each treatment group, selected

consecutively based on protocol numbers to ensure balanced data representation and minimize selection bias. Third, the study was conducted at a single center with a relatively small sample size, which may limit the generalizability of the results to other institutions and broader patient populations. Fourth, only the intraoperative period was evaluated; postoperative hemodynamic changes, patient satisfaction, complication rates, and long-term clinical outcomes were not assessed. Finally, drug dosages and infusion rates were standardized according to institutional protocols, without individual titration based on patient-specific responses. This may not fully reflect the effectiveness of personalized treatment approaches commonly used in clinical practice.

In conclusion, nicardipine provided more effective and stable intraoperative blood pressure control compared to esmolol during awake DBS surgery under MAC. Nicardipine more successfully provided and maintained the target systolic blood pressure with less need for additional antihypertensive medications. Both drugs did not adversely affect intraoperative neurophysiological monitoring. These findings suggest that agents capable of rapid and controlled vasodilation may be preferable for enhancing surgical success and patient safety in awake DBS procedures.

Ethical Approval

Ethical approval for this study was obtained from the Clinical Research Ethics Committee of Ondokuz Mayıs University (Decision No: 2025/91, dated April 15, 2025).

Funding and Conflicts of Interest

The authors declare no conflicts of interest. This study did not receive any financial support from individuals or institutions.

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Authors' Contributions

ET: contributed to study conception, data collection, literature review, and manuscript drafting. BD,YBU: participated in data acquisition, patient record review, and statistical analysis. SB,CK: contributed to clinical data interpretation and critical revision of the manuscript. BBS,EK: supervised the project, reviewed the final version, and provided expert input on the anesthetic protocol. All authors contributed to various stages of the study and share equal responsibility for the final version of the manuscript.

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