Medical Journal of Bakırköy

Med J Bakirkoy 2025;21:76-82
DOI: 10.4274/BMJ.galenos.2025.2024.11-7

Research

Effects of Scalp Block on Postoperative Analgesia in Craniotomy Surgery: A Prospective, Randomized Controlled, Double-Blind Study

Kraniyotomi Cerrahisinde Scalp Bloğunun Postoperatif Analjezi Üzerindeki Etkileri: Prospektif, Randomize Kontrollü, Çift Kör Bir Çalışma

Muhammed Halit Satıcı[1], Mahmut Sami Tutar[1], Betül Kozanhan[1], Yasin Tire[1], İlker Çöven[2], Nuray Altay[3]

[1]University of Health Sciences Türkiye, Konya City Hospital, Clinic of Anesthesiology and Reanimation, Konya, Türkiye

[2]University of Health Sciences Türkiye, Konya City Hospital, Clinic of Neurosurgery, Konya, Türkiye

[3]Harran University Faculty of Medicine, Department of Anesthesiology and Reanimation, Şanlıurfa, Türkiye

ABSTRACT

Objective: Postoperative pain following craniotomy is a significant concern, primarily resulting from surgical incisions and fixation devices. Effective pain management involves various strategies, including systemic analgesics, patient-controlled analgesia, and regional anesthesia techniques. Among regional anesthesia methods, the scalp block provides effective pain control by blocking the nerves innervating the scalp with local anesthetics. This study aimed to evaluate the effectiveness of the scalp block in reducing postoperative pain in craniotomy patients, assessed using the numerical rating scale (NRS).

Methods: Patients were divided into two groups: Group S, receiving the SCALP block, and group C, serving as the control group. Pain scores were recorded at 0, 2, 4, 6, 8, 12, and 24 hours postoperatively. Secondary outcomes included total amount of tramadol administered for rescue analgesia, time to first analgesia, postoperative nausea and vomiting (PONV) incidence, and patient satisfaction.

Results: Group S demonstrated significantly lower NRS scores than Group C at all measured time points ($p<0.001$). The median time to first rescue analgesia was 12 (8-12) hours in group S, while it was 0 (0-1) hours in group C ($p<0.001$). Tramadol consumption was significantly reduced in group S [75 (60-123) mg] compared to Group C [280 (220-280) mg; $p<0.001$].

Conclusion: The scalp block effectively manages postoperative pain, reduces analgesic requirements, and improves patient comfort. It also minimizes complications such as PONV, making it a valuable option for postoperative care following craniotomy.

Keywords: Craniotomy, numerical rating scale scores, rescue analgesia, scalp block

ÖZ

Amaç: Kraniyotomi sonrası postoperatif ağrı, öncelikli olarak cerrahi kesiler ve fiksasyon cihazlarından kaynaklanan önemli bir endişedir. Etkili ağrı yönetimi, sistemik analjezikler, hasta kontrollü analjezi ve bölgesel anestezi teknikleri dahil olmak üzere çeşitli stratejileri içerir. Bölgesel anestezi yöntemleri arasında scalp bloğu, kafa derisini innerve eden sinirleri lokal anesteziklerle bloke ederek etkili ağrı kontrolü sağlar. Bu çalışmanın amacı, kraniyotomi hastalarında postoperatif ağrıyı azaltmada scalp bloğunun etkinliğini, sayısal derecelendirme ölçeği (NRS) kullanılarak değerlendirmektir.

Gereç ve Yöntem: Hastalar iki gruba ayrıldı: Scalp bloğu alan grup S ve kontrol grubu olarak görev yapan grup C. Ağrı skorları postoperatif 0, 2, 4, 6, 8, 12 ve 24. saatlerde kaydedildi. İkincil sonuçlar kurtarma analjezik kullanımı olarak uygulanan toplam tramadol miktarı, ilk analjeziye kadar geçen süre, ameliyat sonrası bulantı ve kusma (PONV) insidansı ve hasta memnuniyeti yer almaktadır.

Bulgular: Grup S, ölçülen tüm zaman noktalarında grup C'den önemli ölçüde daha düşük NRS skorları gösterdi ($p<0,001$). İlk kurtarma analjezisine kadar geçen medyan süre grup S'de 12 (8-12) saat iken, grup C'de 0 (0-1) saatti ($p<0,001$). Tramadol tüketimi grup S'de [75 (60-123) mg] grup C'ye [280 (220-280) mg; $p<0,001$] kıyasla önemli ölçüde azaldı.

Sonuç: Scalp bloğu ameliyat sonrası ağrıyı etkili bir şekilde yönetir, analjezik gereksinimlerini azaltır ve hasta konforunu artırır. Ayrıca PONV gibi komplikasyonları da en aza indirir ve bu da onu kraniyotomi sonrası ameliyat sonrası bakım için değerli bir seçenek haline getirir.

Anahtar Kelimeler: Kraniyotomi, sayısal derecelendirme skalası, kurtarma analjezisi, scalp blok

Address for Correspondence: Muhammed Halit Satıcı, University of Health Sciences Türkiye, Konya City Hospital, Clinic of Anesthesiology and Reanimation, Konya, Türkiye

E-mail: halit_satici@hotmail.com **ORCID ID:** orcid.org/0009-0005-0652-3624

Cite as: Satıcı MH, Tutar MS, Kozanhan B, Tire Y, Çöven I, Altay N. Effects of SCALP block on postoperative analgesia in craniotomy surgery: a prospective, randomized controlled, double-blind study. Med J Bakirkoy. 2025;21:76-82

Received: 28.12.2024
Accepted: 14.01.2025
Publication Date: 25.03.2025

INTRODUCTION

Craniotomy procedures are frequently associated with considerable postoperative pain that may result in hemodynamic disturbances, impaired sleep quality, and prolonged hospital stays (1,2). Pain-induced physiological responses include elevated blood pressure, intracranial pressure, heart rate, and increased morbidity and mortality risks (3,4). While opioids are commonly employed for managing such pain, their use is associated with various adverse effects, such as delayed recovery, sedation, nausea, vomiting, and difficulties in conducting accurate neurological assessments (5). The scalp block, a regional analgesia technique, has gained prominence for its effectiveness in reducing postoperative pain and maintaining hemodynamic stability during neurosurgical interventions (6,7). This method has been recognized as a critical component of multimodal analgesia strategies aimed at controlling pain and mitigating physiological stress responses triggered by surgical trauma (1,3,8-10). Given these challenges and the potential advantages of the scalp block, further investigation is needed into its efficacy in optimizing postoperative pain management and reducing associated complications in craniotomy patients.

This study hypothesizes that implementing the scalp block can significantly lower numerical rating scale (NRS) scores and decrease postoperative analgesic consumption. The primary focus is to evaluate its influence on NRS scores, with secondary objectives including the time to first rescue analgesic administration, total rescue analgesia required, patient satisfaction levels, and the incidence of nausea and vomiting.

METHODS

Ethics Approval and Registration

Ethical approval for the study was obtained from the Clinical Research Ethics Committee of the Harran University (decision no: HRÜ/24.13.01, date: 09.09.2024). It was registered on ClinicalTrials.gov (Identifier: NCT06588751) and conducted in accordance with the 2013 revision of the Declaration of Helsinki and the Consolidated Standards of Reporting Trials guidelines (11). Prior to randomization, all participants provided both written and verbal informed consent. Participants were subsequently allocated randomly into one of two groups: Group S, which received the scalp block, or group C, which was managed with multimodal analgesia.

Patient Population and Inclusion/Exclusion Criteria

The study population consisted of patients aged 18 to 65 years who underwent craniotomy under general anesthesia, and were categorized with an American Society of Anesthesiologists (ASA) physical status classification of I-III. Criteria for exclusion included individuals with contraindications to regional anesthesia, altered consciousness levels, coagulation abnormalities, anti-coagulant therapy, known hypersensitivity to local anesthetics, active infections at the injection site, chronic pain syndromes, or pregnancy.

Randomization

This study was a prospective, randomized, controlled, double-blind, multicenter trial. Patients were allocated to two primary groups using a randomization process managed by an anesthesiologist at each clinic, who utilized these opaque, sealed envelopes to ensure allocation concealment. Group S consisted of patients who received the scalp block, while Group C included those managed with multimodal analgesia alone. To uphold blinding and reduce bias, the anesthesiologists managing the randomization process were excluded from involvement in other parts of the study, and the clinicians performing the scalp block were similarly not involved in data collection or analysis. Additionally, the participants, the interventionist, and the data analyst remained blinded to group assignments. Two anesthesia specialists independently recorded primary and secondary postoperative outcomes.

Standard Anesthesia, and Multimodal Analgesia Protocol

Pulse oximetry, electrocardiography, non-invasive blood pressure, and end-tidal carbon dioxide measurements, were used for monitoring all patients, and standard anesthesia protocols were followed. A 20-gauge intravenous (IV) cannula was inserted, and isotonic fluid therapy was initiated. General anesthesia was initiated using IV midazolam (1 mg), propofol (2 mg/kg), fentanyl (1.5 mcg/kg), and rocuronium (0.6 mg/kg). Maintenance of anesthesia was achieved with remifentanil (0.05-0.1 mcg/kg/min) and propofol (4-12 mg/kg/h), adjusted to maintain hemodynamic stability. All patients underwent the same surgical procedure. All patients were extubated upon completion of the surgical procedure.

Postoperatively, IV morphine (3 mg) was administered, along with 1 g of paracetamol and 8 mg of dexamethasone, prior to the patient's transfer to the intensive care unit (ICU). In the ICU, paracetamol (1 g IV every 8 hours) and tenoxicam (20 mg IV every 12 hours) were given, with tramadol (1 mg/kg IV), provided for NRS scores ≥4. Ondansetron (4 mg IV) was used as needed for nausea and vomiting.

Scalp Block Procedure

After the surgical procedure, patients in group S were placed in a partially seated position. The skin was cleansed

using 5% povidone-iodine for antisepsis and covered with a sterile drape. Each target nerve, including the supraorbital, supratrochlear, zygomaticotemporal, auriculotemporal, greater auricular, greater occipital, and lesser occipital nerves, was injected with 2 mL of 0.25% bupivacaine. These nerves provide sensory innervation to the forehead and scalp. The circumferential scalp block was performed bilaterally with a cumulative dose of 28 mL of 0.25% bupivacaine.

The supratrochlear and supraorbital nerves were anesthetized near the brow, specifically at the superior medial orbital margin and over the palpable supraorbital notch. The zygomaticotemporal nerve was targeted at the posterior edge of the zygomatic arch. The auriculotemporal and greater auricular nerves were blocked at the tragus, adjacent to the pulsating superficial temporal artery, and at the mastoid process. Lastly, the greater and lesser occipital nerves were anesthetized at the medial and lateral portions of the superior nuchal line.

Outcome Measures

The primary outcome was the evaluation of postoperative pain levels, assessed using the NRS, where 0 represents no pain and 10 indicates the worst imaginable pain. Pain scores were documented at 0, 2, 4, 6, 8, 12, and 24 hours post-surgery.

Secondary outcomes included the total amount of tramadol administered as rescue analgesia, the time elapsed before the first dose of rescue analgesics, the requirement for antiemetic medication, the incidence of postoperative nausea and vomiting (PONV), and patient satisfaction levels.

Demographic and clinical characteristics, including age, sex, weight, height, duration of surgery, and ASA classification, were recorded for both groups. Patient satisfaction was evaluated using a 5-point Likert scale, with 1 signifying "completely dissatisfied" and 5 indicating "completely satisfied".

Statistical Analysis

The main objective of this study was to evaluate and compare the NRS scores of the two groups 4 hours after surgery. Based on previous research, a reduction of 2 points in NRS scores between groups was deemed clinically significant for determining the required sample size (12). Preliminary data from a study involving 10 patients undergoing craniotomy who received multimodal analgesia as part of the control group indicated a mean NRS score of 5.5±1.7 at 4 hours postoperatively. Using these findings, an Independent Samples t-test model was applied with a Cohen's D effect size of 1.176. This analysis determined that a minimum of 17 patients per group would be required to achieve 95% statistical power, with an alpha error threshold of 5%. To account for potential dropouts, the final sample size was increased to 20 patients per group, resulting in 40 participants.

The data in this study were analyzed using IBM SPSS Statistics software, version 26.0. The Shapiro-Wilk test was applied to evaluate the normality of the data distribution. Continuous variables were expressed as mean ± standard deviation or as median with interquartile ranges (25^{th}-75^{th} percentiles) based on their distribution. Categorical variables were summarized as frequencies and percentages. For the analysis of continuous variables, the Independent Samples Student's t-test was employed when parametric assumptions were satisfied. When these assumptions were not satisfied, the Mann-Whitney U test was applied. Categorical data were analyzed using Fisher's exact test or the chi-square test. Analysis of Variance was applied to repeat measurements across different time points. Statistical significance was defined as $p<0.05$ for all analyses.

RESULTS

At the outset of the study, 45 patients were screened for eligibility. Five patients opted not to participate and were subsequently excluded. The remaining 40 participants were randomized and managed according to the established study protocol, with equal allocation to the two groups (group C: n=20; group S: n=20) (Figure 1).

The baseline characteristics, such as patient demographics and the duration of surgery, showed no significant differences between the two groups (Table 1).

Primary Outcome

Throughout the first 24 hours after surgery, group C exhibited higher NRS scores than group S at all time points. This difference was statistically significant at the 0, 2, 4, 6, 8, 12, and 24 hours ($p<0.001$) (Figure 2).

Rescue Analgesia Requirement

All patients in group C required rescue analgesia, while four patients in group S did not need it ($p<0.001$). Group C had significantly higher total tramadol consumption within 24 hours [280 (220–280) mg vs. 75 (60–123) mg, $p<0.001$] and a shorter time to the first use of rescue analgesics [0 (0-1) hours vs. 12 (8-12) hours, $p<0.001$]. Significant differences in rescue analgesia were also observed across the time intervals "0-6", "12–24", and "0-24" ($p<0.001$ for all, Table 2).

Adverse Events, Analgesic Characteristics, and the Likert Scale

Throughout the first 24 hours after surgery, PONV occurred in 17 patients (85%) in group C and 4 patients (20%) in group S, with this difference reaching statistical significance (p<0.001). The need for anti-emetic treatment was also notably lower in group S compared to group C (4 patients vs. 17 patients, p<0.001). Additionally, patient satisfaction scores, measured using the Likert scale, were significantly higher in group S, with a median score of 5 (4-5) compared to 2 (2-2) in group C (p<0.001) (Table 3).

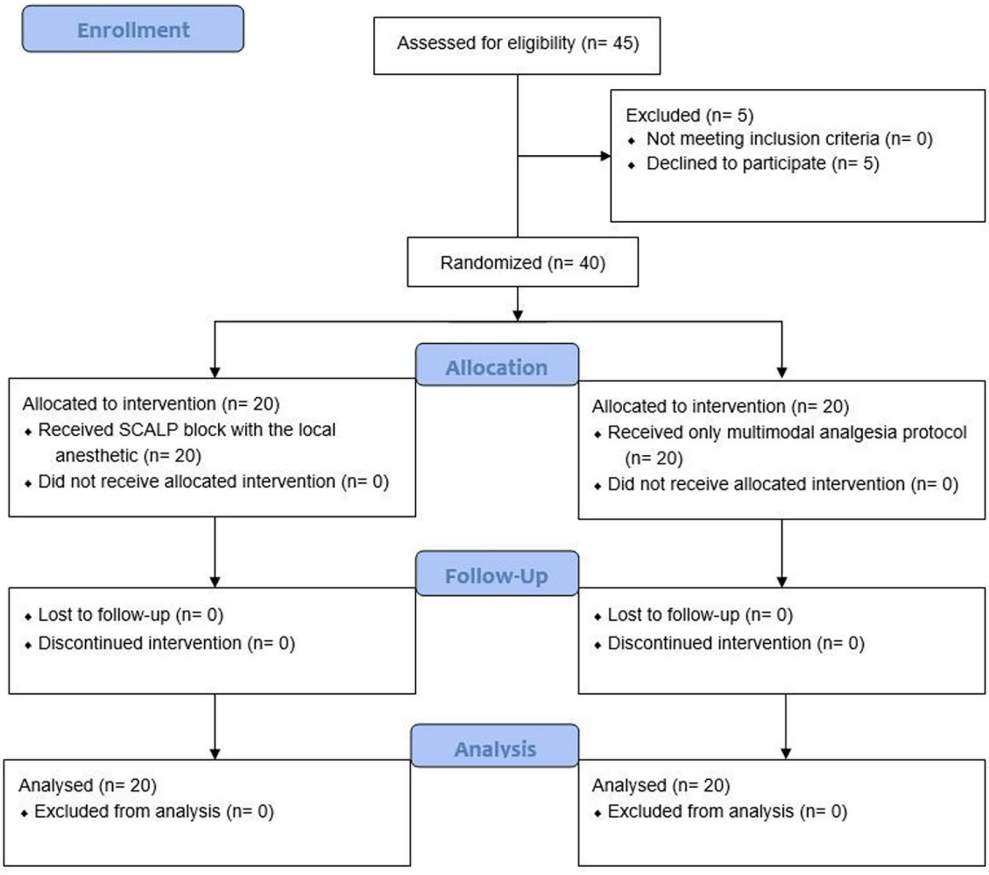

Figure 1. Consolidated standards of reporting trials flow study diagram describing patients' progress through the study

Table 1. Baseline characteristics by groups

Factors	Group C (n=20)	Group S (n=20)	p-value
Age (yr)	51±16	48±17	0.656
Female	9 (45%)	10 (50%)	1
Smoking	4 (20%)	8 (40%)	0.300
Coronary artery disease	2 (10%)	3 (15%)	1
Hypertension	6 (30%)	9 (45%)	0.513
Lung disase	3 (15%)	2 (10%)	1
Height (cm)	168.7±7.2	168.5±8.6	0.921
Weight (kg)	69±6.5	71±12.5	0.540
Surgery time (min)	170±48.1	159.8±30.9	0.428

Data presented as mean ± standard deviation, median (Q1-Q3), or n (%)
yr: year, cm: Centimeter, kg: Kilogram, min: Minutes

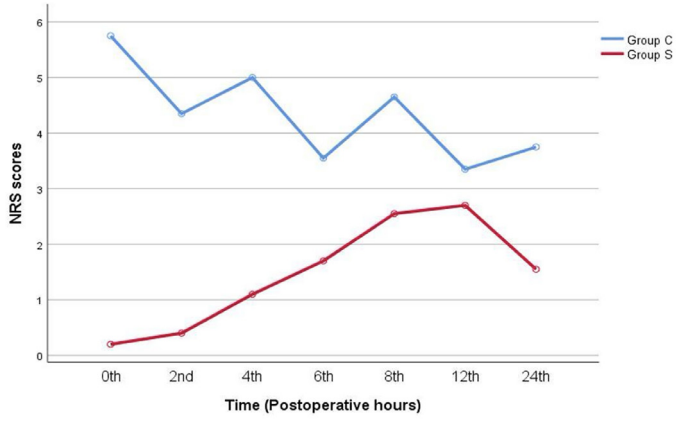

Figure 2. Postoperative numerical rating scores
NRS: Numerical rating scale

Table 2. Postoperative rescue analgesic characteristics among groups

Factors	Group C (n=20)	Group S (n=20)	p-value
First rescue analgesic time (h)	0 (0-1)	12 (8-12)	<0.001
Tramadol consumption (mg)	280 (220-280)	75 (60-123)	<0.001
Rescue analgesic usage, time frame (h)			
0-6	20 (100%)	2 (10%)	<0.001
6-12	20 (100%)	16 (80%)	0.122
12-24	15 (75%)	4 (20%)	<0.001
0-24	20 (100%)	16 (80%)	<0.001

Data are presented as median (Q1-Q3), n (%)
h: Hour, mg: Milligram

Table 3. Comparison of incidence of adverse effects, anti-emetic drug usage, and the likert scale

Factors	Group C (n=20)	Group S (n=20)	p-value
PONV	17 (85%)	4 (20%)	<0.001
The need for antiemetic drug	17 (85%)	4 (20%)	<0.001
Likert scale	2 (2-2)	5 (4-5)	<0.001

Data presented as median (Q1-Q3) or n (%)
PONV: Postoperative nausea and vomiting

DISCUSSION

In this study, patients who underwent a scalp block demonstrated significantly lower postoperative pain scores, reduced rescue analgesic requirements, a decreased incidence of PONV, and a diminished need for antiemetic medications. Additionally, the time to the first analgesic administration was significantly extended, and patient satisfaction levels were higher in this group.

Approximately 80% of patients undergoing craniotomy are believed to endure moderate to severe pain following the procedure (13). Unmanaged acute postoperative pain can trigger physiological responses such as increased heart rate, which may exacerbate myocardial ischemia and hypoxia, thereby elevating the risk of cardiovascular complications (14). Moreover, poorly managed pain during the early postoperative phase increases the likelihood of chronic pain development. Despite advancements in anesthesia and pain management, postoperative analgesia in craniotomy patients remains suboptimal. This is partly attributed to the side effects of frequently used analgesics, such as opioids, which may cause excessive sedation, respiratory depression, and prolonged recovery times. These limitations highlight the challenges of achieving effective pain control in neurosurgical patients (1). Additionally, postoperative pain management in this patient group is particularly challenging due to various neurosurgical complications; such as intracranial bleeding, increased intracranial pressure, cerebral ischemia, seizures, hypertension, air embolisms, cranial nerve injuries, and brain tissue swelling (15).

Earlier research has shown that regional scalp nerve blocks are effective in alleviating postoperative pain and decreasing opioid use in patients undergoing craniotomy. Notably, the preoperative administration of regional scalp nerve blocks has been shown to lower pain scores for up to 16 hours postoperatively (16). These blocks function by inhibiting sodium channels in nerve cell membranes, thereby reducing nerve excitability and conductivity. This mechanism not only mitigates stress responses triggered by surgical trauma but also decreases the need for anesthetic agents. By reducing pain and improving surgical outcomes, scalp nerve blocks enhance rehabilitation and decrease the likelihood of adverse effects (17).

In this study, patients administered a scalp block consistently reported lower pain scores during the first 24 hours after surgery. Additionally, these patients consumed less rescue analgesia and experienced a prolonged time to the first analgesic requirement, often ranging from 8 to 12 hours. These findings suggest that the scalp block is effective for early and late postoperative pain management.

Studies evaluating scalp block recipients have reported significant reductions in anesthetic agent dosages, decreased adverse reactions and complications, and consistently lower pain scores during various postoperative stages (17-19). Furthermore, the reduction in opioid consumption observed in this study not only decreases the risk of dependence but also minimizes opioid-related side effects, such as nausea, sedation, and respiratory depression. The absence of these adverse effects underscores the safety and clinical benefits of the scalp block. Consistent with prior research, patients in this study who received a scalp block exhibited lower maximum NRS scores and required fewer anti-emetics during the first 12 hours postoperatively. However, the total rescue analgesic dosage administered within 24 hours did not differ significantly in certain studies (20).

In the present study, tramadol consumption was significantly lower in the scalp block group compared to the control group. Moreover, nausea or vomiting was reported in only four patients in this group, a finding likely attributable to the reduced opioid usage. The low incidence of PONV further contributed to higher satisfaction scores. Combining a scalp block with systemic analgesics like paracetamol, nonsteroidal anti-inflammatory drugs, and adjunctive

therapies like dexmedetomidine infusion; along with opioids reserved for rescue analgesia, appears to optimize pain control while minimizing side effects in craniotomy patients (21).

One study noted that patients receiving a scalp block without incorporating a multimodal analgesia protocol did not achieve expected outcomes such as reduced pain scores, lower rescue analgesia use, or decreased PONV incidence (22). In this study, the combination of a scalp block with paracetamol and nonsteroidal anti-inflammatory drugs, while reserving tramadol for rescue analgesia, proved to be a practical multimodal approach for postoperative pain control.

Study Limitations

The study only investigated the effects of the scalp block within the initial 24-hour postoperative period. Previous research indicates that postoperative pain is most severe within the first 24 hours following surgery, and effective pain management during this critical window significantly impacts patient recovery, satisfaction, and overall clinical outcomes (1,23). For this reason, our analysis focused exclusively on the first 24 hours. Moreover, the inclusion of various indications for craniotomy, such as cranial masses and intracranial hematomas, may have introduced heterogeneity in the patient population. Future research should explore the influence of the scalp block on long-term recovery outcomes and its impact on patients' overall quality of recovery.

CONCLUSION

The scalp nerve block has demonstrated significant effectiveness in enhancing patient comfort and improving pain management in the postoperative period. Moreover, its ability to reduce undesirable side effects (e.g., nausea and vomiting), lowers the need for analgesic consumption, and enhance patient satisfaction underscores its clinical efficacy and positive contribution to patient-centered care. Based on these findings, the scalp nerve block is recommended as a preferred analgesic approach, particularly for procedures associated with significant postoperative pain, such as craniotomy.

ETHICS

Ethics Committee Approval: Ethical approval for the study was obtained from the Clinical Research Ethics Committee of the Harran University (decision no: HRÜ/24.13.01, date: 09.09.2024).

Informed Consent: Prior to randomization, all participants provided both written and verbal informed consent.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: M.H.S., M.S.T., Concept: M.H.S., B.K., Design: M.H.S., Y.T., Data Collection or Processing: M.H.S., İ.Ç., N.A., Analysis or Interpretation: M.H.S., M.S.T., Literature Search: M.H.S., B.K., Writing: M.H.S., N.A.

Conflict of Interest: We declare that no conflict of interest exists for any of the authors.

Financial Disclosure: The authors declared that this study received no financial support.

REFERENCES

1. Guilfoyle MR, Helmy A, Duane D, Hutchinson PJA. Regional scalp block for postcraniotomy analgesia: a systematic review and meta-analysis. Anesth Analg. 2013;116:1093-102.
2. Hansen MS, Brennum J, Moltke FB, Dahl JB. Pain treatment after craniotomy: where is the (procedure-specific) evidence? A qualitative systematic review. Eur J Anaesthesiol. 2011;28:821-9.
3. Tuchinda L, Somboonviboon W, Supbornsug K, Worathongchai S, Limutaitip S. Bupivacaine scalp nerve block: hemodynamic response during craniotomy, intraoperative and post-operative analgesia. Asian Biomedicine. 2010;4:243-51.
4. Saha P, Chattopadhyay S, Rudra A, Roy S. Pain after craniotomy: A time for reappraisal? Indian Journal of Pain. 2013;27:7-11.
5. Nguyen A, Girard F, Boudreault D, Fugère F, Ruel M, Moumdjian R, et al. Scalp nerve blocks decrease the severity of pain after craniotomy. Anesth Analg. 2001;93:1272-6.
6. Papangelou A, Radzik BR, Smith T, Gottschalk A. A review of scalp blockade for cranial surgery. J Clin Anesth. 2013;25:150-9.
7. Kim HS, Lee SJ, Kim CS, Kim JT. Effect of triamcinolone added to scalp nerve block for postoperative pain management of Moyamoya disease. Korean J Anesthesiol. 2011;61:173-4.
8. Ayoub C, Girard F, Boudreault D, Chouinard P, Ruel M, Moumdjian R. A comparison between scalp nerve block and morphine for transitional analgesia after remifentanil-based anesthesia in neurosurgery. Anesth Analg. 2006;103:1237-40.
9. Pinosky ML, Fishman RL, Reeves ST, Harvey SC, Patel S, Palesch Y, et al. The effect of bupivacaine skull block on the hemodynamic response to craniotomy. Anesth Analg. 1996;83:1256-61.
10. Chaki T, Sugino S, Janicki PK, Ishioka Y, Hatakeyama Y, Hayase T, et al. Efficacy and safety of a lidocaine and ropivacaine mixture for scalp nerve block and local infiltration anesthesia in patients undergoing awake craniotomy. J Neurosurg Anesthesiol. 2016;28:1-5.
11. Moher D, Hopewell S, Schulz KF, Montori V, Gøtzsche PC, et al. CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. BMJ. 2010;340:869.
12. Salaffi F, Stancati A, Silvestri CA, Ciapetti A, Grassi W. Minimal clinically important changes in chronic musculoskeletal pain intensity measured on a numerical rating scale. Eur J Pain. 2004;8:283-91.
13. Moharari RS, Emami P, Neishaboury M, Sharifnia SH, Kianpour P, Hatam M, et al. Scalp nerve block for enhanced pain control and analgesic optimization in elective craniotomy: a randomized controlled trial with analgesia nociception index monitoring. World Neurosurg. 2024;189:e55-e60.

14. Haldar R, Kaushal A, Gupta D, Srivastava S, Singh PK. Pain following craniotomy: reassessment of the available options. Biomed Res Int. 2015;2015:509164.
15. Hwang JY, Bang JS, Oh CW, Joo JD, Park SJ, Do SH, et al. Effect of scalp blocks with levobupivacaine on recovery profiles after craniotomy for aneurysm clipping: a randomized, double-blind, and controlled study. World Neurosurg. 2015;83:108-13.
16. Stieger A, Romero CS, Andereggen L, Heisenberg D, Urman RD, Luedi MM. Nerve blocks for craniotomy. Curr Pain Headache Rep. 2024;28:307-13.
17. Zhang Y, He K, Chen L, Ji K, Zhang Z, Wang W. Role of scalp nerve block in improving the quality of rehabilitation in patients after meningioma resection: A randomized controlled clinical trial. Medicine (Baltimore). 2024;103:38324.
18. Altaf I, Banday J, Naaz S, Ozair E, Punetha P, Challam KS. A randomized control trial on comparative effect of scalp nerve block using levobupivacaine versus fentanyl on the attenuation of pain and hemodynamic response to pin fixation. Bali J Anaesthesio. 2021;5:66-71.
19. Moharari RS, Emami P, Neishaboury M, Sharifnia SH, Kianpour P, Hatam M, et al. Scalp nerve block for enhanced pain control and analgesic optimization in elective craniotomy: a randomized controlled trial with analgesia nociception index monitoring. World Neurosurg. 2024;189:55-60.
20. Lee EK, Lee S, Kwon JH, Lee SH, Park SJ, Kim Y, et al. The efficacy of scalp nerve block in postoperative pain management after microvascular decompression: a randomized clinical trial. J Clin Med. 2023;12:4242.
21. Mestdagh FP, Lavand'homme PM, Pirard G, Joshi GP, Sauter AR, Van de Velde M. PROSPECT working group* of the european society of regional anaesthesia and pain therapy (ESRA). Pain management after elective craniotomy: A systematic review with procedure-specific postoperative pain management (PROSPECT) recommendations. Eur J Anaesthesiol. 2023;40:747-57.
22. Kitsiripant C, Boonyamarn A, Oofuvong M, Prathep S, Kaewborisutsakul A. Cost-effectiveness and efficacy of scalp block for elective supratentorial craniotomy in resource-limited settings: A randomized controlled trial. Surg Neurol Int. 2024;15:191.
23. Song J, Li L, Yu P, Gao T, Liu K. Preemptive scalp infiltration with 0.5% ropivacaine and 1% lidocaine reduces postoperative pain after craniotomy. Acta Neurochir (Wien). 2015;157:993-8.