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Evaluation of the Efficacy of Neuronavigation-guided Scalp Block for Analgesia in Endoscopic Pituitary Surgery

Endoskopik Hipofiz Cerrahisinde Analjezi için Nöronavigasyon Kılavuzluğunda Skalp Bloğunun Etkinliğinin Değerlendirilmesi

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Abstract

Objective: Scalp block is used to manage pain caused by the skull pin during pituitary surgery. The neuronavigation device allows access to preoperative imaging in the perioperative period. The aim of this study was to determine the efficacy and feasibility of neuronavigation-guided scalp blocks.

Method: After ethics committee approval (decision no: 2023-130), patients over 18 years of age who underwent endoscopic pituitary adenoma surgery with scalp block were retrospectively reviewed. After the exclusion criteria, the patients who underwent scalp block were divided into two groups as neuronavigation or anatomical point-guided scalp block (neuronavigation and classic group). The groups were compared with respect to demographic and haemodynamic data, perioperative analgesic consumption, postoperative visual analogue scale (VAS) scores, and complications.

Results: The groups were similar in terms of demographics, haemodynamics, operative times, perioperative opioid use, postoperative VAS scores and analgesic use. Perioperative antihypertensive and postoperative rescue analgesic requirements were statistically similar in the neuronavigation and classics groups [1/4 and 6/9 (n/n); p=0.467 and p=0.537, respectively]. Postoperative rescue analgesic consumption at 24 hours was 87.50±30.62 mg in the neuronavigation group and 100.00±37.5 mg in the classic group (p=0.510). No patient had complications at any time.

Öz

Amaç: Skalp blok, hipofiz cerrahisi sırasında çivili başlığın neden olduğu ağrının yönetiminde kullanılmaktadır. Nöronavigasyon cihazı perioperatif dönemde preoperatif görüntülemeye erişim sağlamaktadır. Bu çalışmanın amacı nöronavigasyon kılavuzluğunda skalp bloklarının etkinliğini ve fizibilitesini belirlemektir.

Yöntem: Etik kurul onayından sonra (karar no: 2023-130), endoskopik hipofiz adenomu cerrahisinde skalp blok uygulanmış 18 yaş üstü hastalar retrospektif olarak incelendi. Dışlama kriterlerinden sonra, skalp bloğu uygulanmış hastalar nöronavigasyon veya anatomik nokta kılavuzluğunda skalp bloğu olarak iki gruba ayrıldı (nöronavigasyon ve klasik grup). Gruplar demografik ve hemodinamik veriler, perioperatif analjezik tüketimi, postoperatif görsel analog skala (VAS) skorları ve komplikasyonlar açısından karşılaştırıldı.

Bulgular: Gruplar demografik veriler, hemodinami, ameliyat süreleri, perioperatif opioid kullanımı, postoperatif VAS skorları ve analjezik kullanımı açısından benzerdi. Perioperatif antihipertansif ve postoperatif kurtarma analjezik gereksinimleri nöronavigasyon ve klasik grubunda benzerdi [sırasıyla 1/4 ve 6/9 (n/n); p=0,467 ve p=0,537]. Postoperatif 24. saat kurtarıcı analjezik tüketimi nöronavigasyon grubunda 87,50±30,62 mg iken Klasik grupta 100,00±37,5 mg'dir (p=0,510). Hiçbir hastada herhangi bir komplikasyon görülmedi.

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Abstract

Conclusion: In this study, the perioperative and postoperative efficacy was found to be similar for both methods. We believe that the use of neuronavigation in regional anaesthesia practice has the potential to increase efficacy and reduce the rate of adverse effects, and is therefore innovative and will find a place in existing anaesthesia methods.

Keywords: Neuronavigation, pituitary surgery, scalp block, skull pin

Öz

Sonuç: Bu çalışmada, perioperatif ve postoperatif etkinlik her iki yöntem için de benzer bulunmuştur. Rejyonel anestezi uygulamasında nöronavigasyon kullanımının etkinliği artırma ve yan etki oranını azaltma potansiyelinin yenilikçi olduğuna ve mevcut anestezi yöntemlerinde yer bulacağına inanıyoruz.

Anahtar kelimeler: Çivili başlık, hipofiz cerrahisi, nöronavigasyon, skalp blok

Introduction

Pituitary adenomas account for a large proportion of intracranial tumour surgery. Endonasal transsphenoidal pituitary surgery (EnTsPS) is used as an endoscopic approach to treat non-functioning pituitary macroadenomas with signs of mass effect and adenomas that continue to function despite medical treatment. As it involves many procedures, it requires careful perioperative anesthetic planning and management (1).

As the operative field in pituitary surgery is extremely limited, various anesthetic techniques, different pharmacological modalities and additional interventions are used to control intraoperative haemodynamic responses (2). Although haemodynamic monitoring is important to maintain cerebral perfusion and prevent the risk of haemorrhage, "controlled" hypotension may have side effects. Multimodal analgesia is effective in the management of postoperative pain and reduces the risk of postoperative complications such as respiratory depression, postoperative nausea and vomiting (3).

The use of skull pin to stabilise the head during cranial surgery produces strong sympathetic activation, resulting in a sudden increase in heart rate (HR) and arterial blood pressure and increased intracranial pressure. Scalp block has been associated with beneficial effects on haemodynamic responses in both primary and secondary outcomes and is used as part of multimodal analgesia (4).

Neuronavigation is an additional system that enhances the safety and comfort of cranial surgery. It allows all anatomical points to be identified using preoperative imaging and accessed in the perioperative period (5). In this study, we aimed to compare neuronavigation or anatomical point-guided scalp blocks.

Materials and Methods

After University of Health Sciences Turkey, Başakşehir Çam and Sakura City Hospital's Ethics Committee approval (decision no: 2023-130, 22 March 2023), American Society of Anaesthesia (ASA) II-III patients aged 18-65 years who underwent EnTsPS and scalp block between 1 October 2021 and 1 April 2022 were retrospectively reviewed for prospectively designed follow-up data.

Patients were excluded if they weighed <50 kg or >100 kg, had a body mass index >30 kg/m^2, an entrance arterial pressure >140 systolic or >90 diastolic, underwent reoperation within 48 hours postoperatively or developed perioperative complications. Patients undergoing scalp block were divided into two groups (neuronavigation and classic group) and compared with respect to demographics, haemodynamics, analgesic requirements, postoperative visual analogue scale (VAS) scores and complications.

In routinely monitored patients, HR, non-invasive blood pressure and peripheral oxygen saturation (SpO_2) were recorded as baseline values. In our hospital, all patients undergoing surgery in EnTsPS receive 0.02 mg/kg intravenous midazolam in the preoperative unit after an eight-hour fast. Patients are started on a fluid infusion of 0.9% NaCl at a rate of 4-6 mL/kg/hour via a 20- or 22-gauge cannula on the dorsum of the hand. Induction is given with 0.5-1 mcg/kg IV fentanyl and 2 mg/kg IV bolus propofol.

Once the patient is ventilated with a face mask, 0.5 mg/kg IV rocuronium is added for muscle relaxation. Direct laryngoscopy and orotracheal intubation with an appropriate size 3-4 Macintosh blade is then performed 2-3 minutes later, followed by left radial artery catheterisation. Maintenance of anesthesia was initiated with 2% sevoflurane inhalation at 0.8-1.0 MAC and a remifentanil infusion of 0.05 mcg/kg/min. The total time from intubation to extubation of the patient is expressed as anesthesia time and the time from surgical incision to extubation is expressed as surgical time.

While the neuronavigation device is used to identify anatomical points in the neuronavigation group, the manual examination is used in the classic group (Figure 1).

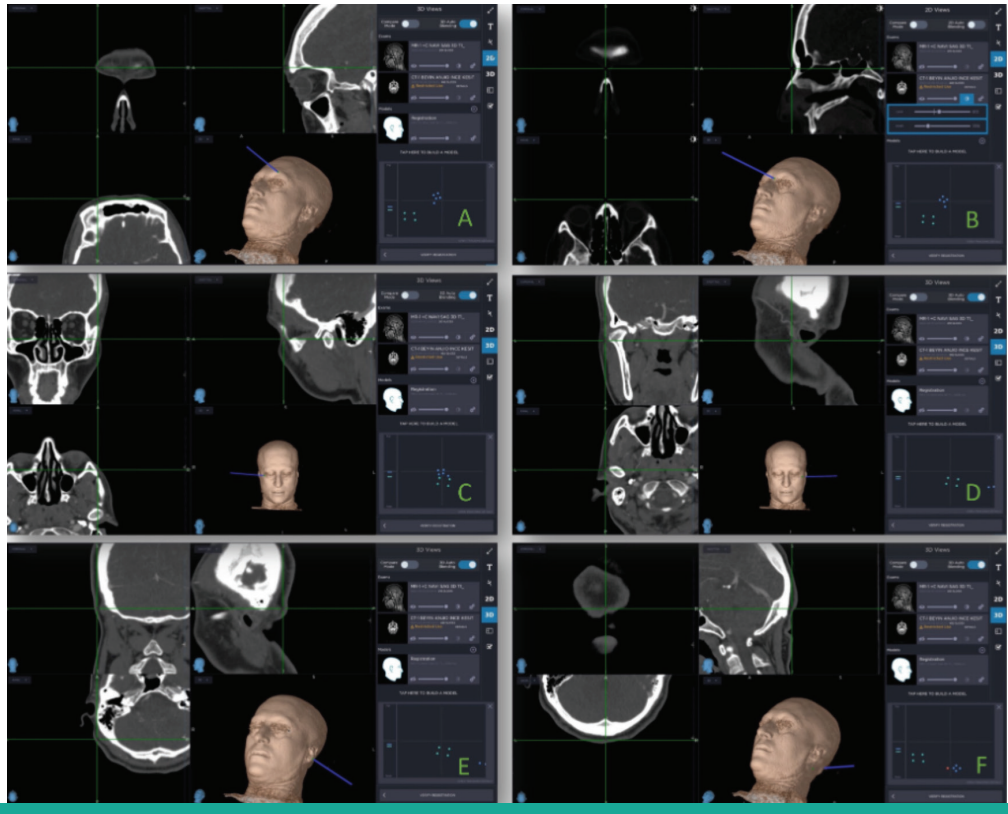

Figure 1. Determination of anatomical points using neuronavigation; (A) Supraorbital nerve (B) Supratrochlear nerve (C) Zygomaticotemporal nerve (D) Auriculotemporal nerve (E) Lesser occipital nerve (F) Greater occipital nerve

The anatomical points where the targeted nerves were applied and the total amounts of local anesthetic bilaterally are shown in Table 1. All patients routinely received 2 mcg/kg fentanyl and 0.5 mg/kg propofol prior to placement of the skull pin. Both groups underwent scalp block in a similar manner; 15 mL of 0.25% bupivacaine was administered after the skull pin in the neuronavigation group and before the skull pin in the classic group. In cases where the surgical team used neuronavigation, a scalp block was applied under neuronavigation guidance. Both block methods were applied by the anesthesiologist.

Before sterilising the surgical area, a sphenopalatine ganglion block is applied; after the cotton-tipped applicator touches the upper border of the middle turbinate, the cotton-tipped applicator is held for 5-10 minutes. This area is filled with a wet dressing to prevent passage from the nasopharynx to the oropharynx and hypopharynx. A nasal decongestant (oxymetazoline hydrochloride) is used to reduce secretions and povidone-iodine is used to sterilise the surgical site.

According to our routine remifentanil infusion algorithm in our hospital, the infusion is increased by 0.01 mcg/kg/min every 5 minutes if the MAP is >65 mmHg; if the MAP is <55 mmHg, the infusion is decreased by 0.01 mcg/kg/min every 3 minutes. The amount of remifentanil required by the patient after intubation, at the start of surgery and at the end of the first and second hour is recorded in mcg/kg/min. If the MAP is <55 mmHg, 5 mg of ephedrine is given as an intravenous bolus, and if the HR is <45 beats/minute, 0.5 mg of atropine is given intravenously. Diltiazem 0.05 mg/kg is given at regular intervals to patients who develop a perioperative need for antihypertensive treatment.

Before the end of surgery, all patients routinely receive 1 mg/kg tramadol citrate and 10 mg/kg paracetamol. Patients routinely receive 2 mg/kg sugammadex before extubation. During the postoperative period, patients are transferred to the post-anesthesia care unit. In the postoperative period, patients received 3x10 mg/kg paracetamol.

Patients' pain status was assessed using a VAS. Postoperative VAS scores were recorded at baseline, 4 hours, 12 hours and 24 hours. While patients with a VAS score of 0-3 do not receive additional analgesia, tramadol 1 mg/kg is routinely administered to patients with a VAS score greater than 3. Ondansetron 4 mg is routinely given for nausea and

Table 1. Nerves and anatomical localizations

Nerves	Anatomic localization	Volume applied (bilaterally)
Supraorbital nerve	Supraorbital notch-lateral supraorbital nerve foramen	1 mL
Supratrochlear nerve	Medial supraorbital nerve foramen-frontomaxillary suture	1 mL
Zygomaticotemporal nerve	Fronto-zygomatic suture	2 mL
Auriculotemporal nerve	Above the zygomatic arch and behind the temporal artery	3 mL
Lesser occipital nerve	SCM posterior junction of skull base	3 mL
Greater occipital nerve	Medial to the occipital artery, Just below the level of the external occipital protuberance	5 mL
3rd occipital nerve	None	None
Totally		**15 mL**

SCM: Sternocleidomastoid muscle

vomiting. The nurse, who was unaware of the patient's treatment during the data collection and recording phase, was enrolled in the study in a double-blind fashion.

The primary objective of this study was to identify anatomical points and tissues when applying the scalp block under neuronavigation guidance. The secondary objective was to assess whether the neuronavigation group had similar outcomes to the classic group in terms of medical management.

Statistical Analysis

In this study, statistical analyses were performed using the NCSS (Number Cruncher Statistical System) 2007 statistical software package (Utah, USA). In addition to descriptive statistical methods (mean ± standard deviation), the distribution of variables was examined using the Shapiro-Wilk normality test. Paired One-Way analysis of variance was used for time comparisons of normally distributed variables, Newman-Keuls multiple comparison test for subgroup comparisons, independent t-test for comparison of paired groups, and chi-squared test for comparison of qualitative data. Results were evaluated at a significance level of $p<0.05$.

Results

The groups were similar in terms of demographics, haemodynamics and operative times (Table 2). Anesthesia time was 235±13.82 minutes in the neuronavigation group and 233.7±10.36 minutes in the classic group (p=0.755). The surgical time was 195.42±16.16 minutes in the neuronavigation group and 200±13.14 minutes in the classic group (p=0.372). Baseline MAP values were 94.56±8.46 mmHg in the neuronavigation group and 89.87±8.76 mmHg in the classic group (p=0.138). After extubation, MAP values were 81.58±4.01 mmHg in the neuronavigation group and 81.17±2.42 mmHg in the classic group (p=0.708).

Perioperative and postoperative analgesic and antihypertensive requirements and postoperative pain scores were similar in the neuronavigation and classic groups (Table 3). Remifentanil consumption after intubation was 0.025±0.012 mcg/kg/min in the neuronavigation group and 0.026±0.015 mcg/kg/min in

Table 2. Demographics, haemodynamics and operative times

		Neuronavigation group (n=12)		Classic group (n=23)		p
Age		50.75±16.37		51.78±11.96		0.832
Gender	Male	6	50.00%	13	56.52%	0.713
	Female	6	50.00%	10	43.48%	
ASA classification (II/III)		9/3		16/7		0.735
BMI (kg/m²)		26.96±5.39		27.72±3.21		0.599
Anesthesia time (minute)		235.00±13.82		233.70±10.36		0.755
Surgical time (minute)		195.42±16.16		200.00±13.14		0.372
MAP (baseline) (mmHg)		94.56±8.46		89.87±8.76		0.138
MAP (after extubation) (mmHg)		81.58±4.01		81.17±2.42		0.708

ASA: American Society of Anaesthesia, BMI: Body mass index, MAP: Mean arterial pressure

Table 3. Perioperative and postoperative analgesic and antihypertensive requirements and postoperative pain score

		Neuronavigation group (n=12)		Classic group (n=23)		p
Remifentanyl consumption (mcg/kg/min)	After intubation	0.025±0.012		0.026±0.015		0.833
	Start of the surgery	0.063±0.007		0.056±0.016		0.090
	1st hour	0.063±0.013		0.053±0.014		0.071
	2 hours	0.042±0.009		0.050±0.015		0.055
Antihypertensive requirement (n)	(-)	11	91.67%	19	82.61%	0.467
	(+)	1	8.33%	4	17.39%	
Required rescue analgesic (24 hours) (n)	(-)	6	50.00%	14	60.87%	0.537
	(+)	6	50.00%	9	39.13%	
Rescue analgesic consumption (24 hours) (mg)		87.5±30.62		100±37.5		0.510
VAS	After extubation	3.00±0.60		2.87±0.55		0.523
	4 hours	2.83±0.58		2.70±0.56		0.499
	12 hours	2.67±0.49		2.96±0.47		0.100
	24 hours	2.67±0.49		2.70±0.47		0.866
	p	0.383		0.248		

VAS: Visual analogue scale

the classic group (p=0.833). Remifentanil consumption at the start of surgery was 0.063±0.007 mcg/kg/min in the neuronavigation group and 0.056±0.016 mcg/kg/min in the classic group (p=0.090). Remifentanil consumption during the first hour of surgery was 0.063±0.013 mcg/kg/min in the neuronavigation group and 0.053±0.014 mcg/kg/min in the classic group (p=0.071). Remifentanil consumption in the second hour of surgery was 0.042±0.009 mcg/kg/min in the neuronavigation group and 0.050±0.015 mcg/kg/min in the classic group (p=0.055).

Perioperative antihypertensive requirements were developed in one patient in the neuronavigation group and four patients in the classic group (p=0.467). In the postoperative period, six patients in the neuronavigation group and nine patients in the classic group required rescue analgesic (p=0.537). Rescue analgesic consumption was 87.50±30.62 in the neuronavigation group and 100.00±37.5 in the classic group (p=0.510).

No statistically significant difference was observed between the mean VAS scores of the neuronavigation and classic groups at baseline, 4 hours, 12 hours, and 24 hours (p>0.05). No statistically significant change was observed between the baseline, 4 hours, 12 hours, and 24 hours VAS scores of the neuronavigation group (p=0.383, p=0.248 respectively). No complications were observed in any patient during the peri- and post-operative period.

Discussion

As the use of nasal tampons after EnTsPS carries a risk of airway obstruction, early and predictable recovery of consciousness is essential. Postoperative extubation should not be performed before full recovery of reflexes, as postoperative application of positive pressure increases intracranial pressure and carries a risk of complications. For these reasons, complete analgesic control with multimodal analgesia becomes more important (6).

In pituitary surgery, a scalp block is used to avoid the additional stress of the skull pin on haemodynamic control (7). Reasons such as the need for multiple injections, individual variation and difficulty in visualisation reduce the chance of success (8). For scalp block application, the 6-point injection is the generally accepted approach. In addition, the innervation area of the 3rd occipital nerve can be included (9). In our cases, this innervation was not targeted because the head was placed in the horizontal plane.

In addition to analgesic control, scalp block results in a longer time to first request for rescue analgesic and fewer analgesics administered. The use of scalp block before or after incision or before or after surgery has been reported to make no difference to the incidence and severity of postoperative pain (10,11). The use of sphenopalatine block in addition to scalp block has been reported to contribute

to haemodynamic stability during craniotomy (12). In our study, the use of scalp block after craniotomy was found to be stable in the perioperative and postoperative periods and did not make a difference.

In cranial surgery, the neuronavigation device provides active access to preoperatively defined imaging, reducing the margin of error in the perioperative period by up to 2 mm (13). This access provides time and safety gains. Considering the limited space and variability of the EnTsPS, the importance of the device is even greater (14). As it is routinely used in these operations, it does not cause us any additional time problems to use it in areas that are difficult to access. The use of the scalp block does not change the accuracy of face recognition (15).

Several studies in the literature suggest the use of neuronavigation to detect variations (8). In imaging techniques, very small peripheral nerves can be imaged at thin section and high Tesla for targeted tissues (16). Using these images, potential variations can be identified and the appropriate injection site can be designed preoperatively. The ability of this device to use all imaging modalities together gives us a wide range of options for detecting relevant tissue. Computed tomography for bone, magnetic resonance imaging for soft tissue or angiography for vascular imaging are becoming increasingly important (17).

The use of neuronavigation is usually preferred in hard-to-reach and high-risk areas that cannot be distinguished macroscopically. There are studies showing its use in the treatment of trigeminal neuralgia as a contribution to deep access (18). No previous study has been conducted in relation to regional approaches to anesthesia. Our aim was to use this technique in anesthetic practice for scalp block. Our study, which we hope will contribute to the literature on its use in selected patient groups, is important and valuable in this regard.

Study Limitations

Our first limitation is that the scalp block may have been performed before the application of the skull pin in the classical group and after in the neuronavigation group. As we felt that it would be ethically inappropriate to target patients for scalp block after skull pin placement, patients received additional anesthesia and analgesia at this time. The retrospective design of this study, the small number of patients, and the lack of equal distribution between groups can be considered as secondary limitations. The fact that such devices are not yet widely used gives us the opportunity to use this device for a limited time before certain surgical procedures. This study is important because it is the first use of this method in regional anesthesia. Further prospective studies with larger case series are needed.

Conclusion

In this study, postoperative analgesic and perioperative haemodynamic data in both groups demonstrated the efficacy of scalp block in accordance with the literature. We believe that the use of neuronavigation and similar new developments in regional anesthesia practice have the potential to increase efficacy and reduce the rate of adverse effects by providing a predictable block with a lower local anesthetic dose. Today, detailed imaging of the peripheral nerves is available, and in the future, direct targeting of the peripheral nerve may be preferred to these reference point determinations in the neuronavigation group by demonstrating patient-specific variations. We believe that such modern imaging techniques and the use of neuronavigation can guide current anesthetic management in the future and take precedence when more is needed.

Ethics

Ethics Committee Approval: University of Health Sciences Turkey, Başakşehir Çam and Sakura City Hospital's Ethics Committee approval (decision no: 2023-130, 22 March 2023).

Informed Consent: Patients give written consent for their images to be published without identifying information for research purposes.

Authorship Contributions

Concept: E.M., O.S., Y.K., B.T., F.G.Ö., Design: E.M., O.S., Y.K., B.T., F.G.Ö., Data Collection or Processing: E.M., O.S., Y.K., Ö.A., F.G.Ö., Analysis or Interpretation: E.M., O.S., Y.K., F.G.Ö., Drafting Manuscript: E.M., O.S., Y.K., F.G.Ö., Critical Revision of Manuscript: E.M., O.S., Ö.A., B.T., Final Approval and Accountability: E.M., O.S., Y.K., B.T., Ö.A., F.G.Ö., Technical or Material Support: E.M., O.S., Y.K., F.G.Ö., Supervision: E.M., O.S., Y.K., B.T., F.G.Ö., Writing: E.M., O.S., Y.K., B.T., Ö.A., F.G.Ö.

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References

1. Lim M, Williams D, Maartens N. Anaesthesia for pituitary surgery. J Clin Neurosci 2006;13(4):413-418.

2. Tsaousi GG, Tsitsopoulos PP, Foroglou NG, Birba V, Tramontana A, Bilotta F. Control of Hemodynamic Responses and Perioperative Outcomes in Transsphenoidal Pituitary Surgery: A Qualitative Systematic Review of the Available Evidence. J Neurosurg Anesthesiol 2022;34(4):372-383.

3. Esfahani K, Dunn LK. Anesthetic management during transsphenoidal pituitary surgery. Curr Opin Anaesthesiol 2021;34(5):575-581.

4. 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(6):1256-1261.

5. Mishra R, Narayanan MDK, Umana GE, Montemurro N, Chaurasia B, Deora H. Virtual Reality in Neurosurgery: Beyond Neurosurgical Planning. Int J Environ Res Public Health 2022;19(3)1719.

6. Dunn LK, Nemergut EC. Anesthesia for transsphenoidal pituitary surgery. Curr Opin Anaesthesiol 2013;26(5):549-554.

7. Sahana BN, Radhapuram SD, Samantaray A, Hemanth N, Pasupuleti H, Mangu HR. Comparison of effects of dexmedetomidine added to ropivacaine versus ropivacaine alone infiltration scalp block for attenuation of the haemodynamic response to skull pin placement in neurosurgical procedures: A double-blind, randomised clinical trial. Indian J Anaesth 2021;65(11):782-788.

8. Rao GSU. Precise scalp block - have another look at scalp innervation. J Neurosci Rural Pract 2023;14(1):1-2.

9. Zetlaoui PJ, Gauthier E, Benhamou D. Ultrasound-guided scalp nerve blocks for neurosurgery: A narrative review. Anaesth Crit Care Pain Med 2020;39(6):876-882.

10. Chen Y, Ni J, Li X, Zhou J, Chen G. Scalp block for postoperative pain after craniotomy: A meta-analysis of randomized control trials. Front Surg 2022;9:1018511.

11. Kulikov A, Tere V, Sergi PG, Pugliese F, Lubnin A, Bilotta F. Preoperative Versus Postoperative Scalp Block Combined With Incision Line Infiltration for Pain Control After Supratentorial Craniotomy. Clin J Pain 2021;37(3):194-198.

12. Garg S, Sachdeva H. The use of sphenopalatine ganglion block for analgesia and attenuation of stress response induced by skull-pin head-holder during neurosurgery. J Anaesthesiol Clin Pharmacol 2020;36(2):147-148.

13. Owen TJ, Chen AV, Frey S, Martin LG, Kalebaugh T. Transsphenoidal surgery: accuracy of an image-guided neuronavigation system to approach the pituitary fossa (sella turcica). Vet Surg 2018;47(5):664-671.

14. Bopp MHA, Sass B, Pojskic M, Corr F, Grimm D, Kemmling A, et al. Use of Neuronavigation and Augmented Reality in Transsphenoidal Pituitary Adenoma Surgery. J Clin Med 2022;11(19):5590.

15. Burbridge MA, Dacanay E, Shields G, Jaffe RA. Scalp blocks do not affect the accuracy of neuronavigation facial recognition registration. J Clin Monit Comput 2023;37(3):761-763.

16. Weiss A, Perrini P, De Notaris M, Soria G, Carlos A, Castagna M, et al. Endoscopic Endonasal Transclival Approach to the Ventral Brainstem: Anatomic Study of the Safe Entry Zones Combining Fiber Dissection Technique with 7 Tesla Magnetic Resonance Guided Neuronavigation. Oper Neurosurg (Hagerstown) 2019;16(2):239-249.

17. Upadhyay UM, Golby AJ. Role of pre- and intraoperative imaging and neuronavigation in neurosurgery. Expert Rev Med Devices 2008;5(1):65-73.

18. Zakrzewska JM, Akram H. Neurosurgical interventions for the treatment of classical trigeminal neuralgia. Cochrane Database Syst Rev 2011;2011(9):CD007312.