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RESEARCH ARTICLE

Intravenous Dexmedetomidine Versus 0.5% Ropivacaine Scalp Block for Attenuation of Hemodynamic Response to Skull-Pin Insertion in Adult Craniotomy: A Prospective Randomized Double-Blind Study

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ABSTRACT

Background: Skull-pin fixation during craniotomy is associated with intense nociceptive stimulation leading to abrupt sympathetic activation, resulting in tachycardia, hypertension, and increased intracranial pressure. Effective attenuation of this hemodynamic response is essential in neurosurgical anaesthesia. This study compared the efficacy of intravenous dexmedetomidine infusion with 0.5% ropivacaine scalp block in attenuating hemodynamic responses following skull-pin insertion during elective craniotomy.

Materials and Methods: In this prospective randomized double-blind comparative study, 130 adult patients undergoing elective craniotomy under general anaesthesia were allocated into two groups. Group D (n=65) received intravenous dexmedetomidine infusion, while Group S (n=65) received bilateral scalp block with 0.5% ropivacaine. Hemodynamic parameters including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) were recorded at baseline, before induction, before pinning, and at 0-10 minutes after skull-pin insertion.

Results: Demographic variables including age, weight, sex distribution, and ASA physical status were comparable between the two groups. Baseline HR was comparable between Group D and Group S (86.62 ± 16.43 vs 83.49 ± 17.26 beats/min; p=0.29). Following skull-pin insertion, HR values were significantly higher in Group D at 1-8 minutes post pinning compared with Group S ($p < 0.05$). Similar trends were observed for SBP, DBP, and MAP, suggesting superior attenuation of hemodynamic responses with scalp block using 0.5% ropivacaine. Both techniques were clinically effective and associated with acceptable hemodynamic stability.

Conclusion: Scalp block with 0.5% ropivacaine demonstrated superior attenuation of the hemodynamic response to skull-pin insertion compared with intravenous dexmedetomidine infusion in adult patients undergoing elective craniotomy. Both interventions were safe and effective, although scalp block provided better control of sympathetic responses during skull-pin application.

Keywords: Dexmedetomidine, Ropivacaine, Scalp block, Craniotomy, Skull-pin insertion, Hemodynamic response, Neuro-anaesthesia

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Introduction

Application of skull-pin fixation devices during craniotomy produces an intense nociceptive stimulus resulting in marked sympathetic activation characterized by abrupt increases in heart rate and arterial blood pressure. In neurosurgical patients, these transient but significant hemodynamic fluctuations may precipitate deleterious consequences including elevated intracranial pressure, cerebral edema, aneurysmal rupture, and compromised cerebral perfusion.[1-3]

The scalp receives extensive sensory innervation from branches of the trigeminal nerve anteriorly and cervical plexus posteriorly, making skull-pin insertion a profoundly painful perioperative event.[4] Multiple pharmacological and regional techniques have been investigated to attenuate these responses, including opioids, beta-blockers, alpha-2 agonists, local anaesthetic infiltration, and scalp nerve blocks.[1,5,6]

Dexmedetomidine, a highly selective alpha-2 adrenergic agonist with sympatholytic, sedative, and analgesic properties, has emerged as an effective adjunct in neuro-anaesthesia. By reducing central sympathetic outflow and catecholamine release, dexmedetomidine attenuates cardiovascular responses to noxious stimuli while preserving respiratory function [7,8].

Scalp block using long-acting local anaesthetics such as ropivacaine provides regional analgesia by blocking sensory nerve supply to the scalp. In addition to attenuating hemodynamic responses during skull-pin fixation, scalp block may contribute to reduced intraoperative anaesthetic requirements and improved postoperative analgesia [1,9,10].

Although both intravenous dexmedetomidine and scalp block are widely employed for attenuation of skull-pin-induced stress responses, evidence comparing their relative efficacy remains limited and inconsistent [5,11,12].

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The present study was therefore undertaken to compare intravenous dexmedetomidine infusion with bilateral scalp block using 0.5% ropivacaine in attenuating the hemodynamic response to skull-pin insertion during elective craniotomy.

Aim and Objectives

To observe and compare the hemodynamic parameters including heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure following skull-pin insertion during craniotomy between the two study groups.

Materials and Methods

Study Design and Setting

This prospective randomized double-blind comparative study was conducted from September 2022 to February 2024, in the Department of Anaesthesiology at N.S.C.B. Medical College and Hospital, Jabalpur.

Study Population

A total of 130 adult patients undergoing elective craniotomy under general anaesthesia requiring skull-pin fixation were enrolled.

Group Allocation

Patients were randomized into two groups:

- Group D (n=65): Received intravenous dexmedetomidine infusion.
- Group S (n=65): Received bilateral scalp block using 0.5% ropivacaine.

Sample Size and Sampling

Sample size was calculated using previously published data from Georgene Singh et al.[5] Based on expected differences in mean hemodynamic parameters, a total sample size of 130 patients (65 per group) was obtained.

Inclusion Criteria

All elective craniotomy patients (both males and females) of age 18-65 years who consented to participate in this study, with ASA physical status I and II, and Preoperative Glasgow Coma Scale (GCS) score of 15 were included in this study.

Exclusion Criteria

Patients with Preoperative heart rate <45 beats/min, left ventricular dysfunction, heart block, patients on Beta-blocker therapy, or Allergy to dexmedetomidine or local anaesthetics were excluded from this study. Also, Pregnancy, Intracranial aneurysm, redo-craniotomy, uncontrolled hypertension, diabetes mellitus, asthma, renal disease, or liver disease patients were excluded.

Study Procedure and Anaesthetic Technique

All patients underwent standard pre-anaesthetic evaluation and were kept nil per oral for 8 hours before surgery. Standard monitoring included electrocardiography, pulse oximetry, non-invasive blood pressure, and capnography. No sedative premedication was administered in either group. General anaesthesia was administered according to standard protocol in both the groups. In Group D, a bolus dose of dexmederomidine (1mcg/kg) was administered over 10 minutes starting at baseline, prior to induction. A maintenance dose of 1mcg/kg/hour was continued from induction till 10 minutes after skull-pin insertion.

In group S, bilateral scalp block was performed by an experienced anaesthesiologist using 30 mL of 0.5% ropivacaine (15 mL on each side), not exceeding the maximum safe dose of 3 mg/kg, soon after endotracheal intubation. Skull pins were applied 10 minutes after the completion of scalp block.

Outcome Measures

Hemodynamic variables including HR, SBP, DBP, and MAP were recorded at:

- Baseline (BL)
- Before induction (BI)
- Before pinning (BP)
- Immediately after pinning (T0)

- 1-10 minutes after pinning (T1-T10)

Any increase in HR or MAP greater than 20% from baseline was treated with either fentanyl 1 µg/kg or propofol 1 mg/kg. Bradycardia was treated with atropine 0.6 mg, while hypotension was treated with ephedrine 5 mg.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using IBM SPSS 26.0 trial version. Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages. Student's t-test was used for comparison of continuous variables and Chi-square/Fisher exact test for categorical variables. A p-value < 0.05 was considered statistically significant.

Results

A total of 130 patients undergoing elective craniotomy requiring skull-pin fixation were enrolled and randomized equally into two groups (65 each). Group D received intravenous dexmedetomidine infusion and Group S received bilateral scalp block with 0.5% ropivacaine. All randomized patients completed the study and were included in the final analysis.

Summary of Findings

The present study demonstrated that both intravenous dexmedetomidine infusion and bilateral scalp block with 0.5% ropivacaine effectively attenuated hemodynamic responses associated with skull-pin insertion during elective craniotomy. However, scalp block provided superior attenuation of heart rate and blood pressure responses during the early post-pinning period.

Discussion

The key finding of the present study was that scalp block with 0.5% ropivacaine provided superior attenuation of sympathetic hemodynamic responses following skull-pin application compared with intravenous dexmedetomidine infusion. Even though both interventions maintained clinically acceptable perioperative hemodynamic stability, patients receiving scalp block demonstrated significantly lower heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) responses during the early post-pinning period.

In the current study, HR values following skull-pin insertion were significantly higher in the dexmedetomidine group from 1-8 minutes after pinning, compared with the scalp block group. Similar trends were observed for SBP, DBP, and MAP, indicating superior attenuation of sympathetic responses with scalp block using 0.5% ropivacaine. These observations suggest that regional blockade of scalp sensory innervation provides more effective suppression of afferent nociceptive transmission during skull-pin insertion than systemic sympatholysis achieved with dexmedetomidine.

Current study results closely correlate with the findings of Singh G et al. (2020),[5] who compared dexmedetomidine infusion with scalp block using 0.5% ropivacaine in patients undergoing elective craniotomy. The authors demonstrated significantly lower HR and MAP values in the scalp block group during the initial minutes following skull-pin insertion and concluded that scalp block provided superior attenuation of hemodynamic responses compared with dexmedetomidine, although both interventions maintained acceptable clinical stability.

Table 1: Demographic and Baseline Characteristics

Variable		*Group D (n = 65)*	*Group S (n = 65)*	*p-value*
Age (years)	Mean ± SD	37.86 ± 12.337	35.98 ± 12.221	0.771
Gender	Male	44 (67.69%)	38 (58.46%)	0.276
	Female	21 (32.31%)	27 (41.54%)	
Weight (kg)	Mean ± SD	59.02 ± 5.603	60.11 ± 5.871	0.695
ASA	Grade I	46 (70.76%)	33 (50.76%)	0.072
	Grade II	19 (29.24%)	32 (49.24%)	

The demographic variables including age, body weight, sex distribution, and American Society of Anesthesiologists (ASA) physical status were comparable between the two groups, and no statistically significant differences were observed between groups.

Table 2: Comparison of Heart Rate Variability Between the Two Groups

Time Interval	*Group D (beats/min) Mean ± SD*	*Group S (beats/min) Mean ± SD*	*p-value*
Baseline (BL)	86.62 ± 16.429	83.49 ± 17.256	0.29
Before induction (BI)	78.63 ± 12.873	82.17 ± 17.13	0.185
Before pinning (BP)	76.74 ± 11.943	80.80 ± 17.156	0.128
Immediately after pinning (T0)	85.55 ± 13.570	86.42 ± 17.529	0.75
1 minute (T1)	93.45 ± 13.249	87.97 ± 17.437	0.04*
2 minutes (T2)	96.52 ± 13.139	91.00 ± 18.162	0.04*
3 minutes (T3)	96.40 ± 12.772	90.68 ± 18.050	0.042*
4 minutes (T4)	97.62 ± 12.032	91.98 ± 17.500	0.034*
5 minutes (T5)	95.29 ± 12.211	89.91 ± 16.795	0.038*
6 minutes (T6)	93.17 ± 12.890	87.91 ± 16.111	0.041*
7 minutes (T7)	90.14 ± 12.474	85.28 ± 15.471	0.052*
8 minutes (T8)	87.94 ± 13.204	82.52 ± 15.793	0.040*
9 minutes (T9)	83.92 ± 12.100	81.05 ± 15.930	0.25
10 minutes (T10)	82.62 ± 11.825	80.00 ± 15.700	0.28

Baseline heart rate values were comparable between the two groups (p=0.29). After the skull pin insertion, it was observed that there was a significant attenuation of increase in heart rate in the scalp block group (using 0.5% ropivacaine) compared to the Dexmedetomidine group ranging from T1 to T8 ($p < 0.05$) and it became comparable by T9 and T10.

Table 3: Comparison of Systolic Blood Pressure Variability Between the Two Groups

Time Interval	*Group D (mmHg) Mean ± SD*	*Group S (mmHg) Mean ± SD*	*p-value*
Baseline (BL)	125.91 ± 9.435	123.54 ± 7.928	0.124
Before induction (BI)	123.17 ± 12.840	121.54 ± 7.357	0.376
Before pinning (BP)	121.57 ± 11.636	121.66 ± 6.972	0.956
Immediately after pinning (T0)	130.82 ± 8.960	128.63 ± 5.867	0.103
1 minute (T1)	136.60 ± 8.953	129.60 ± 6.708	<0.001*
2 minutes (T2)	138.02 ± 7.903	129.02 ± 7.903	<0.001*
3 minutes (T3)	137.65 ± 7.885	128.75 ± 7.569	<0.001*
4 minutes (T4)	133.85 ± 7.505	125.43 ± 6.661	<0.001*
5 minutes (T5)	130.12 ± 7.386	122.49 ± 6.350	<0.001*
6 minutes (T6)	128.06 ± 7.483	121.29 ± 5.886	<0.001*
7 minutes (T7)	125.00 ± 7.226	120.02 ± 5.808	<0.001*
8 minutes (T8)	122.97 ± 7.663	119.00 ± 5.202	0.001*
9 minutes (T9)	120.69 ± 6.159	119.03 ± 4.805	0.089
10 minutes (T10)	117.91 ± 4.208	118.71 ± 4.376	0.290

Baseline systolic blood pressure values were comparable between the two groups (p=0.124). After the skull pin insertion, it was observed that there was a significant attenuation of increase in Systolic Blood Pressure in the scalp block group (using 0.5% ropivacaine) compared to the Dexmedetomidine group ranging from T1 to T8 ($p < 0.05$) and it became comparable by T9 and T10.

Table 4: Comparison of Diastolic Blood Pressure Variability Between the Two Groups

Time Interval	*Group D (mmHg) Mean ± SD*	*Group S (mmHg) Mean ± SD*	*p-value*
Baseline (BL)	78.23 ± 7.024	75.86 ± 7.018	0.057
Before induction (BI)	76.26 ± 8.978	73.98 ± 7.079	0.110
Before pinning (BP)	74.78 ± 8.596	73.82 ± 6.624	0.521
Immediately after pinning (T0)	80.77 ± 7.171	78.74 ± 5.438	0.071
1 minute (T1)	85.32 ± 7.884	78.60 ± 6.222	<0.001*
2 minutes (T2)	86.02 ± 6.587	79.40 ± 6.446	<0.001*
3 minutes (T3)	85.58 ± 6.766	78.46 ± 6.464	<0.001*
4 minutes (T4)	84.03 ± 6.139	76.38 ± 5.787	<0.001*
5 minutes (T5)	81.72 ± 6.266	74.31 ± 5.714	<0.001*
6 minutes (T6)	80.60 ± 6.796	73.05 ± 5.527	<0.001*
7 minutes (T7)	77.35 ± 6.506	72.03 ± 5.545	<0.001*
8 minutes (T8)	76.40 ± 6.420	72.66 ± 5.182	<0.001*
9 minutes (T9)	74.06 ± 6.317	72.72 ± 5.375	0.195
10 minutes (T10)	72.49 ± 5.834	70.52 ± 4.661	0.035*

Baseline diastolic blood pressure values were comparable between the two groups (p=0.057). After the skull pin insertion, it was observed that there was a significant attenuation of increase in Diastolic Blood Pressure in the scalp block group (using 0.5% ropivacaine) compared to the Dexmedetomidine group ranging from T1 to T8 ($p < 0.05$) and it became comparable by T9 and T10.

Table 5: Comparison of Mean Arterial Pressure Between the Two Groups

Time interval	*Group D (mmHg)*	*Group S (mmHg)*	*Statistical significance*
Baseline (BL)	94.12 ± 7.312	91.75 ± 7.022	0.062
Before induction (BI)	91.74 ± 9.73	89.84 ± 6.91	0.202
Before pinning (BP)	90.41 ± 9.31	89.76 ± 6.47	0.644
Immediately after pinning (T0)	97.45 ± 7.149	95.37 ± 5.272	0.061
1 minute (T1)	102.41 ± 7.76	95.60 ± 6.12	<0.001*
2 minutes (T2)	103.4 ± 6.6	96.5 ± 6.4	<0.001*
3 minutes (T3)	102.96 ± 6.668	95.23 ± 6.610	<0.001*
4 minutes (T4)	100.64 ± 6.127	92.73 ± 5.852	<0.001*
5 minutes (T5)	97.92 ± 6.071	90.37 ± 5.759	<0.001*
6 minutes (T6)	96.44 ± 6.480	89.13 ± 5.447	<0.001*
7 minutes (T7)	93.24 ± 6.303	88.02 ± 5.323	<0.001*
8 minutes (T8)	91.92 ± 6.83	88.11 ± 5.19	<0.001*
9 minutes (T9)	89.60 ± 5.884	88.16 ± 4.959	0.133
10 minutes (T10)	87.63 ± 4.901	86.58 ± 4.274	0.197

Baseline Mean Arterial Pressure (MAP) values were comparable between the two groups (p=0.062). After the skull pin insertion, it was observed that there was a significant attenuation of increase in MAP in the scalp block group (using 0.5% ropivacaine) compared to the Dexmedetomidine group ranging from T1 to T8 ($p < 0.05$) and it became comparable by T9 and T10.

Similarly, Srinivasan A et al. (2025)[11] compared intravenous dexmedetomidine infusion with levobupivacaine scalp block for attenuation of the hemodynamic response to skull-pin insertion during craniotomy and observed improved perioperative hemodynamic stability in patients receiving scalp block. The authors suggested that effective blockade of scalp nociceptive afferent pathways contributed to better attenuation of sympathetic responses following skull-pin application.

The efficacy of scalp block in attenuating hemodynamic responses during craniotomy has been consistently demonstrated in previous literature. Study by Pinosky ML et al. (1996) [1] were among the earliest investigators to describe scalp block as an effective technique for reducing the hemodynamic response to craniotomy by blocking sensory branches of the trigeminal and cervical nerves. Their study demonstrated significantly improved intraoperative hemodynamic stability and reduced anaesthetic requirements following scalp block with bupivacaine.

Likewise, Kaushal et al. (2024) [13] evaluated the efficacy of ketamine as an adjuvant to scalp block in patients undergoing elective craniotomy for supratentorial glioma and demonstrated improved perioperative hemodynamic stability during noxious neurosurgical stimulation. Their findings further support the effectiveness of scalp block-based techniques in attenuating sympathetic responses during craniotomy.

Study by Geze S et al. [6] further showed that scalp block significantly reduced hemodynamic responses and stress hormone release compared with local infiltration techniques during skull-pin fixation. Similarly, Yang X et al. (2019) [14] compared scalp nerve block with local anaesthetic infiltration in patients undergoing craniotomy for cerebral aneurysms and demonstrated improved perioperative hemodynamic stability, reduced inflammatory response, and better postoperative analgesia in patients receiving scalp nerve block. Their findings further support the role of scalp block in attenuating sympathetic responses during neurosurgical procedures.

A systematic review and meta-analysis of randomized controlled trials conducted by Luo M et al. (2023) [10] evaluating scalp nerve block during craniotomy and demonstrated that scalp block significantly attenuated perioperative hemodynamic responses and improved intraoperative hemodynamic stability. Their findings further support the concept that interruption of peripheral nociceptive transmission effectively suppresses skull-pin-induced sympathetic activation.

The present findings are also supported by Bala R et al. (2022) [9], who compared intravenous dexmedetomidine with local infiltration of ropivacaine for attenuation of stress response during skull-pin insertion in craniotomy patients. The authors stated that ropivacaine infiltration provided attenuation of hemodynamic responses comparable or superior to dexmedetomidine while maintaining satisfactory perioperative stability.

Dexmedetomidine has gained widespread acceptance in neuro-anaesthesia because of its sedative, analgesic, anxiolytic, and sympatholytic properties without causing significant respiratory depression. Through selective stimulation of central presynaptic $\alpha 2$-adrenoceptors, dexmedetomidine decreases sympathetic outflow and catecholamine release, thereby attenuating cardiovascular responses to painful stimuli [7,8].

Several more studies have found beneficial effects of dexmedetomidine during neurosurgical procedures. Studies by Bekker AY et al. (2001) [7] and Ard JL et al. (2005) [8] demonstrated effective perioperative sedation and hemodynamic control with dexmedetomidine during awake craniotomy. In a recent study, Deetayart S et al. (2023) [15] evaluated dexmedetomidine infusion for attenuation of hemodynamic responses to skull-pin holder placement and found significant reductions in HR and blood pressure compared with placebo-treated patients. However, despite these beneficial sympatholytic effects, the present study demonstrated comparatively greater hemodynamic fluctuations in the dexmedetomidine group than in the scalp block group.

The superiority of scalp block observed in the present study may be explained physiologically by complete interruption of nociceptive afferent impulses before transmission through trigemino-vascular pathways. In contrast, dexmedetomidine primarily attenuates central sympathetic responses without completely abolishing peripheral nociceptive input. Consequently, scalp block may provide more direct and effective attenuation of skull-pin-induced sympathetic stimulation.

In addition, Reddy A et al. (2025) [12] conducted a systematic review and meta-analysis evaluating dexmedetomidine as an adjuvant to local anaesthetics in scalp nerve block and concluded that scalp block effectively attenuates hemodynamic responses to noxious perioperative stimuli during craniotomy.

The clinical implications of the present study are particularly relevant in modern neuro-anaesthesia practice, where prevention of secondary neurological injury through meticulous hemodynamic control is essential. Based on the present findings, bilateral scalp block with 0.5% ropivacaine appears to provide superior attenuation of sympathetic responses to skull-pin insertion compared with intravenous dexmedetomidine infusion and may therefore represent a more effective strategy for incorporation into multimodal neuro-anaesthetic protocols for elective craniotomy.

Conclusion

The present prospective randomized double-blind study demonstrated that both intravenous dexmedetomidine infusion and bilateral scalp block with 0.5% ropivacaine effectively attenuated the hemodynamic response to skull-pin insertion during elective craniotomy. However, scalp block with 0.5% ropivacaine provided significantly superior attenuation of heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure responses during the early post-pinning period compared with intravenous dexmedetomidine.

Based on the findings of this study, bilateral scalp block using 0.5% ropivacaine may be considered a more effective and reliable technique than intravenous dexmedetomidine infusion for attenuation of sympathetic responses associated with skull-pin insertion in adult patients undergoing elective craniotomy. Incorporation of scalp block into multimodal neuro-anaesthetic protocols may further contribute to improved intraoperative hemodynamic control and enhanced perioperative neurosurgical care.

Strengths of the Study

The major strengths of this study include its prospective randomized double-blind design, adequate sample size, standardized anaesthetic protocol, and comprehensive evaluation of multiple hemodynamic parameters following skull-pin insertion. The study directly compared two commonly employed neuro-anaesthetic strategies in a clinically relevant neurosurgical population, thereby enhancing the practical applicability of the findings. In addition, serial hemodynamic measurements at multiple predefined time intervals allowed detailed assessment of the temporal hemodynamic response following skull-pin fixation.

Limitations of the Study

The current study was conducted at a single tertiary care center, which may limit generalizability of the findings to broader patient populations. Long-term postoperative outcomes, postoperative pain scores, recovery characteristics, and patient satisfaction were not evaluated. Also, serum catecholamine or stress hormone levels were not measured, which could have provided objective biochemical correlation of sympathetic attenuation. Future multicentric studies with larger sample sizes and extended postoperative evaluation may further validate the clinical benefits of scalp block in neurosurgical anaesthesia.

Ethical Approval

Taken from ethical committee of N.S.C.B. Medical College and Hospital, Jabalpur. Informed consent obtained.

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