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REVIEW

Regional scalp block for post-craniotomy pain management in children: a scoping review

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Abstract

In children undergoing craniotomy, the impact of postoperative pain on recovery is receiving growing recognition. While opioids are often the primary treatment, their administration requires a delicate balance between achieving sufficient analgesia and mitigating side effects like sedation, nausea, vomiting, and respiratory depression. We review the emerging adjunct treatment modality regional scalp block (RSB) infiltration for post-craniotomy pain. Postoperative pain after pediatric craniotomy can be challenging to manage and may contribute to unnecessary suffering as well as the development of long-term neurocognitive and psychological sequelae. Pain during the PICU stay is also a major risk factor for post-PICU syndrome, which involves persistent impairments in children's physical, cognitive, or mental health persisting beyond acute hospitalization. Despite increasing awareness and treatment strategies for post-craniotomy pain in adults, significant gaps remain in understanding its assessment and management in children. This review examines the current literature surrounding post-craniotomy pain management in children with a special emphasis on RSB, a treatment option increasingly used in adults and children. RSB has been shown in randomized trials to reduce postoperative pain and opioid use. However, while pediatric perioperative trials support its safety and feasibility, robust clinical evidence supporting RSB's efficacy for post-craniotomy pain in children remains limited, hindering wider translation into clinical standard. RSB infiltration is an emerging and promising technique for pediatric post-craniotomy pain management. Early evidence suggests it is both safe and effective, with potential to enhance postoperative recovery and to be integrated into clinical practice. Further research is critical to validate initial findings and better define the benefits across diverse pediatric populations.

Keywords Craniotomy · Pain · Postoperative pain · Children · Regional scalp block · Local analgesia

Introduction

Post-craniotomy pain management in children admitted to Pediatric Intensive Care Units (PICUs) is a complex problem. Pain assessment is complicated by the patient's limited communicative abilities, and research remains equivocal concerning which pain management strategies are optimal for improving children's outcomes [1, 2]. Postoperative pain in children often requires multimodal treatment, and insufficient pain control leads to unnecessary suffering for both the child and family. Notably, inadequate pain control is associated with both short- and long-term consequences, including altered stress response, delayed recovery, and the development of chronic pain syndromes [3]. Pain is known to be a major contributing factor to the development of Post-(P)

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ICU syndrome, a syndrome originally described in adults but increasingly recognized in children [4]. Post-PICU syndrome describes an impairment in physical, cognitive, or mental health in children hospitalized in the PICU that persists beyond the acute hospitalization [2, 5].

In children undergoing cranial procedures, such as craniotomies for brain tumors, craniofacial procedures, or surgery for cranial trauma, narcotics in combination with acetaminophen/paracetamol are widely used and have been suggested to be both effective and low risk [6–11]. However, the use of narcotic pain medications may interfere with critical neurologic assessments or contribute to hemodynamic instability, leading to undertreatment [12]. Moreover, concerns regarding opioid dependence and long-term neurodevelopmental effects have increased interest in opioid-sparing analgesic strategies [13].

In adults, regional scalp block (RSB, sometimes referred to synonymously as scalp nerve block) has been increasingly used as an additional tool in the treatment of post-craniotomy pain, and numerous studies have demonstrated its safety and efficacy [10, 12, 14–16]. Although the safety profile of RSB is well established in children due to its use in craniofacial surgeries and awake craniotomies, evidence evaluating its efficacy for post-craniotomy pain management in pediatric patients remains limited to only two RCTs [17–20].

This scoping review aims to map and critically evaluate the existing literature on RSB for post-craniotomy pain management in pediatric patients, with the goal of informing future research and clinical implementation.

Methods

This scoping review was conducted using the PRISMA-ScR scoping review guidelines (Fig. 1). We synthesized existing literature on postoperative pain management following pediatric craniotomy, with a focus on the use of RSB.

A narrative review was used to explore existing literature in both adult and pediatric populations. Studies were chosen using PubMed as the primary database through a structured search using predefined terms including combinations of "pediatric," "craniotomy," "postoperative pain," "regional scalp block," and "local anesthetics." This search strategy allows for articles to be selected based on relevance to pediatrics, RSB, postoperative analgesia, safety outcomes, and opioid reduction. Additional relevant articles were identified by reviewing references from key studies. Titles and abstracts were screened for relevance, and full texts were reviewed to determine eligibility.

Studies were included if they evaluated pediatric patients (0–18 years old) undergoing craniotomy and evaluated postoperative pain management strategies, with particular emphasis on the use of RSB. All study designs were considered, including randomized controlled trials (RCTs), cohort studies, and case reports.

Articles were chosen based on their aim and alignment with the primary objective of this scoping review: to explore current practice and evidence regarding postoperative pain

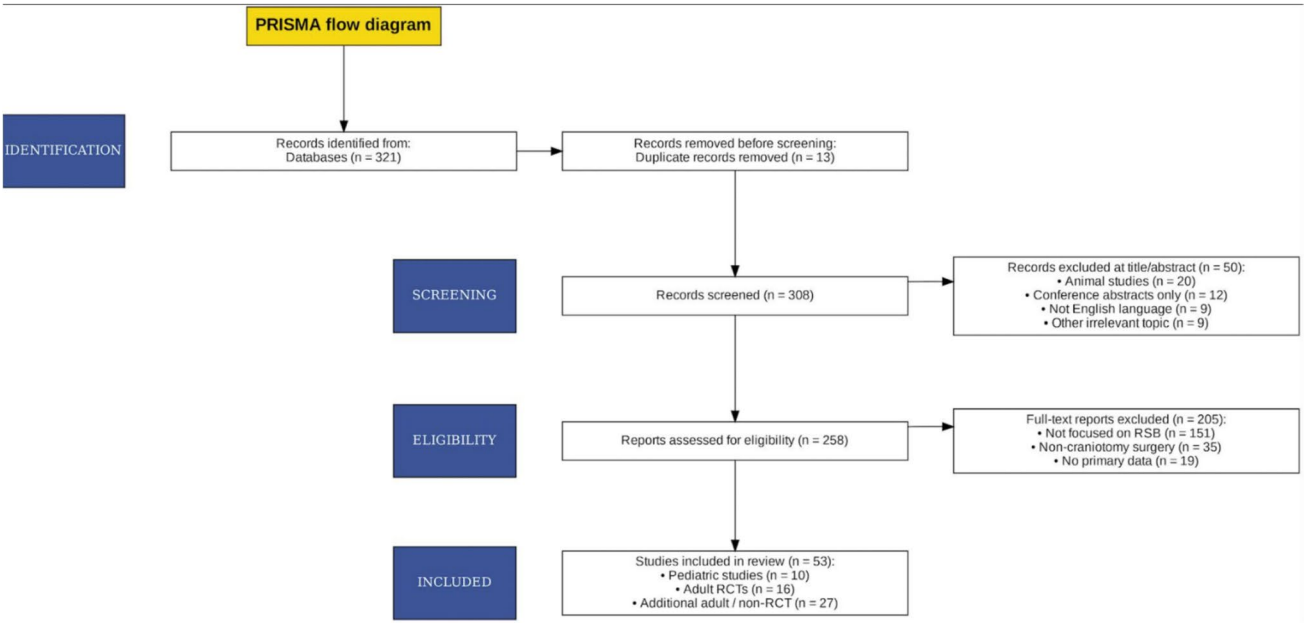

Fig. 1 PRISMA flow diagram

management in pediatric craniotomy with a focus on RSB. No restrictions were placed in terms of publication dates and language during the search for peer-reviewed articles. Included studies were also assessed for level of evidence (Supplementary Table 1).

The data charting process did not involve a formal data charting tool. Instead, the findings were summarized based on reported outcomes. Details were manually extracted, including the study design, population size, interventions used, reported outcomes, and any noted adverse effects. The results were synthesized by themes to highlight the efficacy, safety, and feasibility of RSB. Studies were first grouped by population (adults versus children) and further categorized by study design, time of intervention (preoperative, intraoperative, postoperative), and type of analgesic agent used. The findings were thematically organized by the outcomes of interest, which are as follows: pain intensity, opioid usage, hemodynamic stability, and adverse effects.

Conducting this narrative review allows for patterns to be identified while also revealing the limited research available and highlighting the need for further exploration of RSB as a pain management method in children post-craniotomy.

Post-craniotomy pain

Pain after craniotomy was historically considered to be minimal to modest, as some studies suggested that adult craniotomy patients may require fewer immediate postoperative analgesics than do patients undergoing other procedures due to the relatively low number of pain receptors in the dura and the pain insensitivity of the brain parenchyma [21]. However, this view has been increasingly challenged by accumulating evidence demonstrating that post-craniotomy pain is frequently severe and often inadequately treated [22]. Recent studies have found that post-craniotomy pain reaches moderate to severe intensity in roughly two of every three patients within the first 48 h postoperatively and is often poorly controlled [22]. One study prospectively assessing postoperative pain in 52 adult craniotomy patients reported that 84% experienced moderate to excruciating pain in the first 24 h after a craniotomy, with 55% experiencing severe to excruciating pain [23]. Additional clinical studies have emerged reporting moderate to severe pain in up to 60% of patients [24–26]. Younger age has also been found to be a risk factor for increased post-craniotomy pain [27].

The assessment and treatment of post-craniotomy pain in children continue to lag behind advances made in adult populations, largely due to the lack of dedicated research and standardized pediatric protocols [28]. Pain assessment has improved with the increasing availability of pediatric pain assessment tools, although challenges persist in assessing pain among children with cognitive disabilities [29]. Given the unique physiological and psychological considerations in pediatric patients, there is an urgent need for targeted research to optimize pain management strategies in this population. Table 1 presents the most relevant pediatric studies, including the two existing RCTs evaluating RSB in the pediatric population.

Postoperative pain management in children often consists of a multimodal approach and varies widely. While opioids can serve as potent analgesics, side effects like sedation, nausea, and vomiting limit their use [6, 7]. Particularly in the context of neurosurgery, it may be difficult to determine whether postoperative symptoms like nausea and vomiting are side effects of opioid analgesics or are related to the surgical procedure and underlying disease process itself [12, 22]. Further, after craniotomies in which the dura was opened, it is important to avoid the Valsalva maneuver or other activities that could provoke sudden changes in intracranial pressure, and vomiting acts as one of the most severe Valsalva maneuvers. Co-administration of opioids and acetaminophen is commonly employed as a means of facilitating opioid use at reduced doses [6–9]. Given their undesirable side effects on platelets, nonsteroidal anti-inflammatory drugs are relatively contraindicated, although some studies have demonstrated their efficacy and safety [30, 31].

Scalp infiltration for post-craniotomy pain management in adults

In adult populations, both scalp infiltration and RSB are well-established means of pain control. Here, we summarize the agents involved, general technique, risks, and efficacy of RSB in managing post-craniotomy pain.

Commonly used agents

Most local anesthetic agents exert their effects by inhibiting voltage-gated sodium channels and thereby inhibit nerve conduction [33]. These agents fall into one of three categories: ester cocaine derivatives, amide cocaine derivatives, and natural derivatives, which are less commonly used and have variable mechanisms of action. The most common agents used in patients undergoing craniotomy are of the amide-cocaine derivative class and include lidocaine (2%), bupivacaine (0.5%), and ropivacaine (0.75%). Of these, lidocaine has the fastest onset and shortest duration of action, while ropivacaine has the longest duration of action [33]. Given its pharmacokinetic profile, ropivacaine may be the most suitable agent for achieving durable postoperative pain control.

Table 1 Studies investigating post-craniotomy pain in children

Study	*N*	Methods and agents used	Results and outcome	Adverse effects
Smyth et al., 2004 [30]	50	Compares pain control between two groups with sub-occipital craniotomy • 25/50 children underwent a scheduled regimen of acetaminophen (10 mg/kg) and ibuprofen (10 mg/kg) alternating every 2 h and 25/50 received analgesic medication when requested	Scheduled regimen group • Lower pain scores • Shorter stay in hospital • Decreased need for narcotics and antiemetics	Not reported
Ou et al., 2008 [8]	71	Compares • Continuous morphine infusion (CMI) (52% of children) • Acetaminophen and codeine (non-CMI) (48% of children)	No difference between the two groups in terms of pain control	• 30% nausea in CMI group on POD and 63% nausea and vomiting on POD 1 • One child with respiratory depression in non-CMI • No sedation in both groups
Bauer et al., 2010 [31]	51	Ibuprofen alternating with acetaminophen	• 55% of children required postoperative morphine for breakthrough pain • 75% required < 3 doses of morphine	• 18% with small postoperative hemorrhage in the tumor cavity • 2% with moderate postoperative hemorrhage in the tumor cavity
Warren et al., 2010 [9]	71	52% of patients received continuous morphine infusion 47% received acetaminophen and codeine Pain score recorded on each day for three POD	No difference in pain control between the two groups	• Nausea in 57% of children on POD 1 and in 27% of children on POD 2 • No respiratory or hemorrhage events in either group
Teo et al., 2011 [32]	52	Parenteral morphine given to all patients postoperatively	• 42.3% of children had at least one episode of severe pain postoperatively that required rescue analgesia • Children > 7 years required more morphine for longer duration	• No respiratory depression • No nausea or vomiting
Bronco et al., 2014 [7]	213	90% of children received rectal codeine and paracetamol after surgery	• 16% of children with moderate pain on POD0 • 19% with severe pain on POD0 • 2% with pain until POD2	• 11% delirium in PACU • 9% sedation • 6% nausea and vomiting • 2% respiratory depression • 14% other complications associated with disease or surgery
Maxwell et al., 2014 [6]	200	Three different protocols: • Continuous opioid infusion + low dose prophylactic naloxone infusions in 75/200 in BCH • Intermittent, PRN IV opioids in 75/200 in CHOP • Intermittent, PRN IV opioids 50/200 in JHH POD2 or 3 • Oral oxycodone and acetaminophen	• 90% of children had mild pain on POD 0 • No difference between the three protocols in controlling postoperative pain and length of stay in hospital	• 33–58% vomiting • 42–56% nausea • 0–2% altered mental status • No respiratory depression
Xing et al., 2019 [28]	320	RCT, four groups were compared: • Normal saline (control) • Fentanyl group • Morphine group • Tramadol group	• Morphine was superior regarding pain control 1–16 h after surgery • Fentanyl and tramadol groups showed lower pain scores in comparison to control group • More NSAIDs used in control group	• Nausea and vomiting higher in tramadol group • No respiratory depression recorded in any group

Table 1 (continued)

Study	*N*	Methods and agents used	Results and outcome	Adverse effects
Ning et al., 2022* [19]	50	RCT, two groups: • 0.2% ropivacaine for RSB • Normal saline (control)	• Ropivacaine significantly relieved postoperative pain up to 8 h postoperatively • RSB reduced opioid consumption • RSB reduced intraoperative propofol and remifentanil use	• There was no difference in the incidence of postoperative nausea and vomiting between groups
Xiong et al., 2024* [20]	180	RCT, three groups: • 0.3% ropivacaine for preoperative RSB • 0.3% ropivacaine for postoperative RSB • Normal saline (control)	• Postoperative RSB reduced total opioid use up to 48 h after surgery relative to control • Preoperative RSB reduced total opioid use up to 4 h after surgery relative to control • Postoperative RSB significantly reduced opioid use up to 24 h after surgery relative to preoperative RSB • Pre- and postoperative RSB reduced pain scores up to 4 h after surgery	• No significant difference in postoperative nausea and vomiting among the three groups • Three cases of respiratory depression, all of which occurred in the control group

Abbreviations: *BCH* Boston Children's Hospital, *CHOP* The Children's Hospital of Philadelphia, *CMI* continuous morphine infusion, *JHH* Charlotte R. Bloomberg Children's Center at the Johns Hopkins Hospital, *POD* postoperative day, *RCT* randomized controlled trial, *RSB* regional scalp block

*These studies are the two RCTs that have investigated RSB specifically in pediatric patients

In many cases, these agents are combined with adjuvants like epinephrine. The addition of epinephrine reduces local perfusion, prolonging local action and simultaneously minimizing adverse effects by reducing systemic absorption [34]. Other adjuvants have also been found to augment efficacy, including fentanyl, dexmedetomidine, and tetrodotoxin [22]. While many of these are interesting alternatives to conventional local analgesic cocktails, evidence remains limited, and they are not widely adopted in neurosurgical practice.

Anatomic considerations in regional scalp blockade and infiltration

The use of local infiltration prior to incision is common practice, likely owing to minimal additional training requirements and a low risk profile. The site of the planned incision is infiltrated with the local anesthetic agent of choice, with or without additional infiltration after closure. The main considerations revolve around the local incisional anatomy, avoiding arteries and prior craniotomy defects, and ensuring that the total dose delivered is within safe limits (a more important consideration for children younger than 1 year of age).

Regional scalp block requires strong knowledge of the scalp's innervation, and success is predicated on the provider's capacity to accurately localize the six nerves supplying the scalp (Fig. 2). The supra-trochlear nerve innervates the inferior aspect of the forehead, and RSB is directed to the medial corner of the orbit just lateral to the nasion. The supraorbital nerve innervates the forehead and anterior scalp, extending nearly to the lambdoidal suture, and may be targeted at the incisura supraorbitalis. The zygomaticotemporal nerve provides innervation to a small and variable region of the lateral forehead and temporal regions; its course is also variable, making effective blockade challenging. The auriculotemporal nerve innervates the posterior temporal scalp and parts of the ear. Its RSB is directed 1.0–1.5 cm ventral to the tragus, and caution must be exercised to avoid the superficial temporal artery and branches of the facial nerve. The posterior part of the scalp is innervated medially by the greater occipital nerve and laterally by the lesser occipital nerve. The greater occipital nerve may be targeted along the superior nuchal line one third of the distance (about 4 cm) from the occipital protuberance to the mastoid process, while the lesser occipital nerve may be targeted two-thirds of the distance (about 7 cm) along that same line. The greater occipital nerve also runs alongside the occipital artery, and care must be taken to avoid accidental puncture of the vessel during nerve block. Thus, in addition to knowledge of these landmarks, the provider must also consider regional vasculature and potential surgical defects to accordingly adjust the plan and maximize safety.

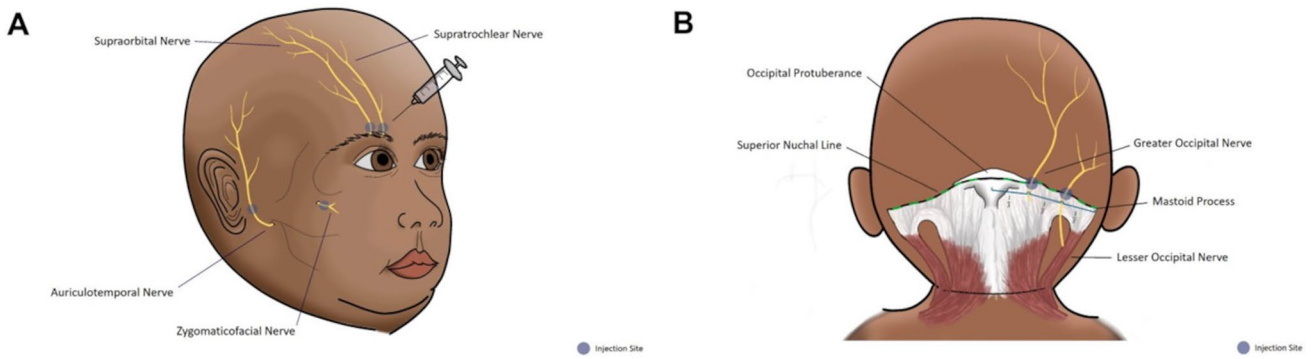

Fig. 2 Regional scalp block anatomy. Scalp innervation is illustrated in yellow, with blue circles denoting the target sites for regional scalp block injections. **A** Right anterolateral view illustrating, from medial to lateral, the right supratrochlear, supraorbital, zygomaticotemporal, and auriculotemporal nerves, with circles to denote the associated target sites. **B** Posterior view illustrating, from medial to lateral, the right lesser occipital and greater occipital nerves, again with circles denoting the associated injection target sites for regional scalp block. The superior nuchal line is indicated with the target sites for greater occipital nerve and lesser occipital nerve block located one third and two-thirds, respectively, along the line from the occipital protuberance to the mastoid process

Risks of regional scalp blockade

The primary risks of RSB derive from the volume of local agent administered, the proximity of vascular structures, postsurgical changes in regional anatomy, and mechanical injury to the target nerve. These risks are mildly increased in smaller children given the volume of local agent that can be safely administered. However, these complications are overall uncommon. In the two existing RCTs examining RSB in children, no RSB-related complications were noted [19, 20]. One systematic review of seven randomized clinical trials (RCTs) including 320 patients did not identify any complications of regional blockade [15]. Aside from RCTs, one case report described the successful use of serial peripheral nerve blocks for an Ommaya reservoir insertion in a very low–birth-weight neonate [35]. The patient remained hemodynamically stable.

There has been one report of delayed emergence from anesthesia after surgery for a Chiari decompression, which was attributed to generous bupivacaine "field block" and resultant migration of anesthetic agent from the site of injection (Munis 2006), though the authors actually describe peri-incision infiltration rather than RSB per se [36]. More generally, a review of malpractice claims related to regional anesthesia, which was not restricted to cranial cases, identified 62 claims between 2006 and 2016, noting that brachial plexus blocks were most likely to result in litigation [37]. This litigation most often cited "technical knowledge and operator performance" as a contributing factor to the injury [37]. Thus, the risk profile of RSB, as is the case with any procedure, is heavily dependent on the operator's anatomical knowledge and technical expertise.

Postoperative pain outcomes in the adult population

There have been a moderate number of RCTs examining the efficacy of RSB in controlling post-craniotomy pain in the adult population (Table 2). In 2001, Nguyen and colleagues conducted an RCT comparing post-closure ropivacaine RSB with saline and found that RSB reduced postoperative pain scores without reducing overall postoperative pain medication use [10]. A slightly larger study by Bala and colleagues reported that postoperative RSB significantly reduced pain scores and pain medication use within the first 24 h post-procedure [14]. Of the 17 RCTs examining RSB efficacy, eight detected a significant reduction in postoperative pain medication use, though one noted an increase in postoperative narcotic use at only the 4-h postoperative time point [14, 38–41]. Ten detected a significant reduction in postoperative pain scores. A 2017 systematic review and meta-analysis found that when the seven trials through 2010 were combined, RSB was associated with an overall reduction in postoperative narcotic requirements, though this was in comparison to placebo or no block rather than local infiltration [15]. Only one study demonstrated superiority of RSB compared with local infiltration [41].

In 2021, two RCTs evaluating adult patients undergoing craniotomies found that RSB significantly improved hemodynamic control, reduced postoperative pain scores, and decreased opioid consumption [16, 49]. A more recent 2022 meta-analysis including 12 RCTs and 833 patients from 2001 to 2021 found that RSB significantly decreased pain scores in the early and intermediate postoperative period, could prolong the time to the first use of rescue analgesics, and could decrease the use of additional analgesics, including opioids, without any significant difference in complication rates [50]. Notably, a

Table 2 Randomized controlled trials examining regional scalp block efficacy in adults

RCTs in adults				
Study	Design	*N*	Intervention	Key results
Nguyen et al., 2001 [10]	RCT, supratentorial craniotomy	30	Postoperative RSB (1) Ropivacaine (2) Saline	– RSB reduced postoperative pain scores – No difference in postoperative pain medication use
Bala et al., 2006 [14]	RCT, supratentorial craniotomy	40	Postoperative RSB (1) Bupivacaine epinephrine (2) Saline	– RSB reduced the incidence of moderate-to-severe postoperative pain during first 12 h – RSB increased time to first postoperative pain medication – RSB reduced postoperative pain medication use
Ayoub et al., 2006 [38]	RCT, craniotomy	50	Postoperative (1) IV morphine (2) Bupivacaine lidocaine RSB	– RSB with marginally increased pain medication use at only 4 h postoperative, not at other shorter or longer time points
Hernandez et al., 2007 [39]	RCT, supratentorial craniotomy	30	Preoperative RSB (1) Bupivacaine (2) Saline	– RSB reduced postoperative morphine use – RSB increased time to first postoperative pain medication (731 min vs. 80 min) – RSB reduced pain score for first 16 h postoperative – RSB reduced postoperative nausea/vomiting
Gazoni et al., 2008 [42]	RCT, supratentorial craniotomy	30	Preoperative RSB (1) Ropivacaine (2) GA alone	– RSB reduced hemodynamic response to head-holder application – No difference in postoperative narcotic requirement
El-Dahab, 2009 [43]	RCT, supratentorial craniotomy	80	Preoperative RSB (1) Bupivacaine epinephrine (2) GA alone	– RSB reduced postoperative pain score *Unable to confirm block vs. infiltration, paper not PubMed indexed
Hwang et al., 2015 [44]	RCT, frontoparietal craniotomy for unruptured aneurysm clipping	52	Postoperative RSB (1) Levobupivacaine (2) Saline	– RSB reduced postoperative pain scores – RSB reduced postoperative PCA use – RSB reduced postoperative antihypertensive requirement – RSB reduced postoperative nausea/vomiting
Jayaram et al., 2016 [1]	RCT, craniotomy	40	Preoperative RSB (1) Maxillary target (2) Conventional block	– Maxillary target had reduced postoperative pain scores at 12 h postop
Can et al., 2017 [45]	RCT, craniotomy	90	Preoperative RSB (1) Bupivacaine (2) Levobupivacaine (3) Saline	– RSB reduced hemodynamic response to head-holder application and incision – RSB reduced intraoperative analgesic requirement – No effect on postoperative pain control
Akcil et al., 2017 [40]	RCT, infratentorial craniotomy	47	Preoperative RSB (1) Bupivacaine (2) Infiltration (3) Remifentanyl alone	– RSB reduced hemodynamic response to skin incision – RSB reduced postoperative pain score – RSB and infiltration reduced 24 h postoperative morphine consumption

Table 2 (continued)

RCTs in adults				
Study	Design	*N*	Intervention	Key results
Yang et al., 2019 [41]	RCT, craniotomy for aneurysm clipping	57	Preoperative RSB (1) Ropivacaine (2) Ropivacaine infiltration (3) GA alone	– RSB reduced serum inflammatory markers and cytokine levels 6–24 h postop – RSB eliminated hemodynamic response to incision – RSB reduced postoperative pain scores – RSB reduced postoperative narcotic use – RSB reduced postoperative nausea/vomiting
Rigamonti et al., 2019 [46]	RCT, supratentorial craniotomy	89	Intraoperative RSB (1) Bupivacaine, epinephrine (2) Saline	– No effect on postoperative pain score at 24 h – No effect on total mean hydromorphone consumption at 24 h – No effect on time to discharge from the hospital or the PACU
Hussien et al., 2020 [47]	RCT, supratentorial craniotomy	30	Preoperative RSB (1) Bupivacaine lidocaine epinephrine (2) Fentanyl intravenous	– No difference in complications between RSB and intravenous analgesia
Yang et al., 2020 [48]	RCT	88	Preoperative RSB (1) Ropivacaine (2) Saline	– RSB reduced pain scores up to 2 h postoperatively at 0.2% and 0.33% and up to 4 h postoperatively at 0.5% – RSB reduced hemodynamic response to incision, drilling, and sawing skull bone
Carella et al., 2021 [16]	RCT, supratentorial craniotomy	60	Preoperative RSB (1) Levobupivacaine (2) Saline	– RSB reduced hemodynamic response to skull-pin fixation and skin incision – RSB decreased cumulative morphine consumption – RSB decreased postoperative pain scores
Skutuliene et al., 2021 [49]	RCT, craniotomy	141	Intraoperative RSB or infiltration (1) Bupivacaine lidocaine epinephrine (2) Paracetamol ketoprofen	– RSB decreased postoperative pain scores at 24 h – RSB reduced the need for rescue analgesics

Abbreviations: *GA* general anesthesia, *POD* postoperative day, *RCT* randomized controlled trial, *RSB* regional scalp block

2024 meta-analysis by Duda et al., comprised of adult patients, found that RSB reduced post-craniotomy pain at 2–48 h and also reduced opioid consumption up to 48 h postoperatively, comprising the first level 1 A evidence evaluating scalp block efficacy in craniotomy in any patient population [12].

Regional scalp block in children

Emerging evidence supports the safety and efficacy of RSB as a post-craniotomy pain management tool in children. Case reports and retrospective analyses suggest that RSB is feasible and safe for pain and peri-interventional purposes [51–53]. Two randomized controlled trials focusing on pediatric post-craniotomy pain provide the strongest available evidence regarding this methodology's safety [19, 20].

In 2022, Ning et al. conducted the first single-center, prospective, double-blind RCT to evaluate RSB with 0.2% ropivacaine versus normal saline in 50 children aged 2–12 years old [19]. They found that RSB reduced intraoperative propofol and remifentanil consumption rates, postoperative fentanyl use, and significantly relieved postoperative pain intensity up to 8 h postoperatively. Notably, the rates of nausea and vomiting were no different between the two groups.

A larger, second pediatric RCT was published in 2024, further supporting the use of postoperative RSB as an analgesic strategy [20]. The RCT enrolled 180 children (ages 1 to 12) undergoing elective craniotomy and compared analgesic effects by assigning participants to one of three groups: preoperative, postoperative, or nonblocking control group. Postoperative RSB significantly reduced sufentanil use up to 48 h postoperatively and resulted in lower early pain scores compared to both preoperative RSB and controls [20]. No RSB-related complications were observed. This study illustrates RSB's utility as a safe, targeted, opioid-sparing, and sustained pain management approach.

In a study evaluating RSB with levobupivacaine as a complement to routine analgesic protocols in 32 children undergoing craniosynostosis repair, the nerve block, done at the beginning of the surgery under general anesthesia, was found to potentially provide improved hemodynamic stability during incision and closure [51]. Two regional hematomas were observed by the surgeon, and no other side effects were noted. No changes in hemodynamics were observed, and the authors postulated that this technique could lead to reduced opioid use [51].

Though not specifically for post-craniotomy pain (and thus not included in Table 1), a case control study by Festa et al. in 2020 found that RSB was effective for reducing immediate postoperative pain in 13 patients younger than 2 years old who underwent cranioplasty for craniosynostosis [52]. The use of RSB significantly reduced the number of pharmacological interventions needed for pain treatment in the PICU, and children who received scalp blocks also began oral feeding earlier than the control groups [52].

Given the evidence from adult populations demonstrating significant reductions in pain scores and opioid consumption, there is a compelling rationale for further investigation of RSB in pediatric patients, in whom post-craniotomy pain is an underrecognized issue.

Limitations

This review has several limitations. First, the number of studies examining RSB in pediatric patients is low, with only two RCTs identified, both published within the last 3 years. Most existing data on RSB are derived from studies in adults, which limits its generalizability to pediatric populations due to physiological, anatomical, and pharmacokinetic differences. Additionally, existing pediatric studies vary widely in methodology, anesthetic agent used, block timing (e.g., preoperative versus postoperative), outcome measures, and patient ages, which makes direct comparisons challenging. To this end, although the narrative synthesis employed here allows for thematic grouping, it fails to provide a quantitative synthesis of outcomes. Pain outcomes are also subjective, and therefore, inconsistencies in how pain is measured can limit cross-study comparability.

Conclusion

RSB is a well-established technique for managing post-craniotomy pain in adults, with numerous RCTs and meta-analyses demonstrating its efficacy in reducing both pain and opioid consumption. The data in children are more limited, but the available evidence including two RCTs suggests RSB is both safe and effective in children, mirroring benefits observed in adult populations. Given the potential long-term consequences of undertreated post-craniotomy pain in children, regional scalp blocks represent a promising yet underutilized option in pediatric neurosurgery and should be integrated into multimodal pain management strategies for children undergoing craniotomy. Further, large-scale, high-quality clinical trials are needed to confirm these findings, optimize block protocols, and define the long-term safety and effectiveness of RSB in diverse pediatric neurosurgical populations.

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Data availability Data are available from the corresponding author upon reasonable request.

Declarations

Ethics approval This study was exempted by the Institutional Review Board due to the study being a review and thus lacking any identifiable patient data.

Conflict of interest No authors declare any conflicts of interest.

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