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Infraclavicular versus costoclavicular approaches to ultrasound-guided brachial plexus block: a systematic review and meta-analysis

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Nerve block;

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Abstract

Background: The costoclavicular approach to brachial plexus block may have a more favorable anatomy than the classic infraclavicular approach. However, there are conflicting results in the literature regarding the comparative effectiveness of these two techniques.

Methods: We systematically searched for Randomized Controlled Trials (RCTs) comparing costoclavicular with infraclavicular brachial plexus blocks for upper extremity surgeries on

MEDLINE, EMBASE, and Ovid. The outcomes of interest were sensory and motor block onset times, performance times, block failure, and complication rate. We performed statistical analyses using RevMan 5.4 and assessed heterogeneity using the Cochran Q test and I^2 statistics. We appraised the risk of bias according to Cochrane's Risk of Bias 2 tool.

Results: We included 5 RCTs and 374 patients, of whom 189 (50.5%) were randomized to undergo costoclavicular block. We found no statistically significant differences between the two techniques regarding sensory block onset time in minutes (Mean Difference [MD = -0.39 min]; 95% CI -2.46 to 1.68 min; p = 0.71); motor block onset time in minutes (MD = -0.34 min; 95% CI -0.90 to 0.22 min; p = 0.23); performance time in minutes (MD = -0.12 min; 95% CI -0.89 to 0.64 min; p = 0.75); incidence of block failure (RR = 1.59; 95% CI 0.63 to 3.39; p = 0.63); and incidence of complications (RR = 0.60; 95% CI 0.20 to 1.84; p = 0.37).

Conclusion: This meta-analysis suggests that the CCV block may exhibit similar sensory and motor onset times when compared to the classic ICV approach in adults undergoing distal upper extremity surgery, with comparable rates of block failure and complications.

Introduction

Infraclavicular (ICV) and Costoclavicular (CCV) brachial plexus blocks are commonly employed for regional anesthesia and analgesia in upper extremity surgical procedures.[1,2] These techniques offer comprehensive coverage of the upper limb from axilla to digits while minimizing the risk of hemi-diaphragmatic paresis, as observed with more proximal approaches.[3,4]

The traditional ICV approach to the brachial plexus involves accessing the lateral infraclavicular fossa adjacent to the coracoid process. In this region, the three cords of the brachial plexus lie deep to the pectoralis muscles and are spatially separated (Fig 1A). Their proximity to the axillary artery varies significantly, making it rare to visualize three cords simultaneously.[5,6] On the other hand, the CCV approach is performed at the same level as the axillary artery but more medially in the costoclavicular space. Here, the cords are superficial and tightly clustered together (Fig. 1B). Consequently, some authors suggest that the CCV approach offers a more advantageous anatomical configuration, resulting in reduced interindividual variability.[5] Furthermore, visualization of the brachial plexus is typically easier with the CCV approach, requiring less needle manipulation during the procedure.[2,7-11]

The potential impact of the aforementioned anatomical and sonoanatomical advantages on block outcomes remains uncertain. To bridge this knowledge gap, we conducted a comprehensive systematic review and meta-analysis of Randomized Controlled Trials (RCT) comparing CCV and ICV blocks in patients undergoing distal upper extremity surgery. Our evaluation focused on sensory block onset time, motor block onset time, performance time, incidence of block failure, and complications with each approach.

Methods

Eligibility criteria

We included only studies meeting all the following eligibility criteria in this meta-analysis: (1) RCTs; (2) Comparing CCV and ICV approaches for brachial plexus block; (3) Using ultrasound-guidance; (4) In patients older than 18-years of age undergoing elbow, forearm, or hand surgeries; and (5) Reporting any of the clinical outcomes of interest. We excluded: (1) Overlapping populations, defined as studies with overlapping institutions and recruitment periods; and (2) Non-randomized studies.

Search strategy and data extraction

We systematically searched MEDLINE, EMBASE, and Ovid for RCTs meeting the eligibility criteria, published from inception to November 2022. The search strategy we used for all databases consisted of: (infraclavicular OR “lateral sagittal” OR paracoracoid) AND costoclavicular. Two different authors conducted the search independently (STA and RAL). We last searched all databases on November 15, 2022. We applied no language restrictions. Three authors (STA, RAL, and NPD) independently extracted baseline characteristics and outcome data based on predefined criteria. Disagreements in study screening or data extraction were resolved through consensus among the authors.

We prospectively registered the protocol for this study in the International Prospective Register of Systematic Reviews (PROSPERO) with registration number CRD42022372297. We conducted and reported the systematic review and meta-analysis in accordance with the Cochrane Handbook for Systematic Reviews of Interventions and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA).[12]

Endpoints

The outcomes of interest were (1) Sensory block onset time; (2) Motor block onset time; (3) Performance time; (4) Incidence of block failure; and (5) Incidence of complications. Sensory onset time was evaluated using ice in four of the included studies, employing the scale: 0 = normal, 1 = analgesia, and 2 = anesthesia.[13-16] One trial used the pinprick test, adopting the following scale: 0 = no sensation, 1 = pinprick present.[17]

Motor block assessment was conducted through movement evaluation in four RCTs[13-16] (2 = normal, 1 = paresis, 0 = paralysis), whereas one trial[17] employed the Lovett rating scale (6 = normal muscular force, 5 = slightly reduced muscular force, 4 = pronounced reduction in muscular force, 3 = slightly impaired mobility, 2 = pronounced mobility impairment, 1 = almost complete paralysis, 0 = complete paralysis). Performance time was defined differently in the studies. In one RCT,[13] it was determined as the sum of imaging and needling times, whereas in the other RCTs,[14-17] it referred to the duration from local infiltration to the completion of local anesthetic injection.

Block failure was defined as the occurrence of patient-reported pain during surgery. The assessment of complications encompassed a pooled analysis of hoarseness, hemi-diaphragmatic paralysis, paresthesia, vascular puncture, and Horner Syndrome.

Quality assessment

Considering that only RCTs were included in the analysis, we employed the Cochrane Risk of Bias assessment tool version 2 (Rob-2) to evaluate the risk of bias.[18] Two authors (STA and RAL) independently conducted the risk assessment, and any disagreements were resolved through consensus.

Due to the limited number of included studies, we could not conduct a comprehensive assessment of publication bias. The utility of funnel plots in detecting bias is limited when the sample size is small, and the Egger test is not recommended unless there are at least 10 studies included in the analysis.[19]

We assessed the overall strength of evidence for each outcome using the guidelines created by the Grades of Recommendation, Assessment, Development, and Evaluation (GRADE) working group. Using the GRADEpro Guideline Development Tool, two independent authors (STA and RAL) rated the certainty of evidence as high (⨁⨁⨁⨁), moderate (⨁⨁⨁⊖), low (⨁⨁⊖⊖), or very low (⨁⊖⊖⊖).[20]

Statistical analysis

We conducted a comprehensive statistical analysis to assess the associations between the variables of interest. We estimated Risk Ratios (RR) for categorical outcomes, and Mean Differences (MD) for continuous outcomes. To account for variations in study designs and populations, we employed inverse variance weighting under DerSimonian-Laird random effects models to calculate the association measures along with their respective 95% Confidence Intervals (95% CI) and *p*-values.

In order to evaluate the extent of heterogeneity, we quantified it using τ^2 and I^2 statistics, and further assessed it using Cochran's Q test. We performed sensitivity analyses for all outcomes using the leave-one-out method, which allowed us to assess the impact of each individual study on the overall pooled analysis. Additionally, we conducted exploratory subgroup analyses for key outcomes that were available for further investigation.

We conducted the statistical analysis using R version 4.3.0 (R Foundation for Statistical Computing).

Results

Study selection and characteristics

Our initial search of the databases yielded 138 results, which we subsequently refined by removing duplicated and ineligible studies. After this process, 7 studies remained and underwent a thorough review by two authors based on predefined eligibility criteria. Complete agreement was reached between the authors. Ultimately, we included 5 RCTs comparing CCV and ICV blocks in the analysis (Fig. 2). These trials were published between 2017 and 2021 and included a total of 374 patients, with 189 (50.5%) allocated to the CCV block group. The age of the patients ranged from 18 to 80 years, and the American Society of Anesthesiologists (ASA) physical status varied from I to III. Body Mass Index (BMI) ranged from 18 to 40 $kg.m^{-2}$. Key characteristics of the included studies are summarized in Table 1.

Pooled analysis

We found no statistically significant differences between CCV and ICV blocks in terms of sensory block onset time (MD = -0.39 min; 95% CI -2.46 to 1.68 min; $p = 0.71$; $I^2 = 70\%$; 5 RCTs; 374 patients; Fig. 3A) or motor block onset time (MD = -0.34 min; 95% CI -0.90 to 0.22 min; $p = 0.23$; $I^2 = 13\%$; 3 RCTs; 204 patients; Fig. 3B).

Our subgroup analysis examining different local anesthetics yielded comparable results. In studies using Ropivacaine, we found no statistically significant differences in

sensory onset time between groups (MD = -0.50 min; 95% CI -9.65 to 8.65 min; $p = 0.02$; $I^2 = 81\%$; 2 RCTs; 165 patients; Fig. 3A). Similarly, for studies using a mixture of Bupivacaine with Lidocaine, we found no statistically significant differences in sensory onset time (MD = -1.54 min; 95% CI -2.92 to -0.16 min; $p = 0.56$, $I^2 = 0\%$; 2 RCTs; 144 patients). The same applies to studies utilizing only Bupivacaine (MD = -0.51 min; 95% CI -1.06 to 0.04 minutes; 1 RCTs; 100 patients). Regarding motor block onset time, we found the results were consistent regardless of the drugs administered (Fig. 3B).

We did not identify any statistically significant differences between ICV and CCV approaches in terms of performance time (MD = -0.12 min; 95% CI -0.89 to 0.64 min; $p = 0.75$; $I^2 = 96\%$; 5 RCTs; 374 patients) (Fig. 4).

Regarding the incidence of block failure, we found no statistically significant difference between the two groups. In the CCV group, there was a total of 12/189 cases of block failure, while in the ICV group, there were 7/185 cases (RR = 1.59; 95% CI 0.63 to 3.39; $p = 0.63$; $I^2 = 0\%$; 5 RCTs; 374 patients).

Similarly, with respect to the incidence of complications, we found both groups demonstrated comparable results. In the CCV group 4/189 patients experienced complications, while in the ICV group 7/185 patients encountered complications (RR = 0.60; 95% CI 0.20 to 1.84; $p = 0.37$; $I^2 = 0\%$; 5 RCTs; 374 patients).

Sensitivity analysis

When we excluded the study by Brown in 2020, the effect estimates revealed a clear superiority of the CCV approach over the ICV approach in terms of achieving sensory block onset (MD = -0.67; 95% CI -1.18 to -0.16) (Supplementary Fig. S1). We found the Baujat plot (Supplementary Fig. S2) revealed that Brown contributed the most to the overall heterogeneity and exerted the greatest influence on the overall result. These combined findings suggest that the presence of heterogeneity in the study design may have impeded the ability to draw a definitive conclusion favoring the CCV approach.

However, we found the leave-one-out analysis did not yield any notable differences compared to the main analysis regarding motor block onset, as depicted in Supplementary Figure S3. Moreover, the sensitivity analysis provided additional support for the neutral findings concerning comparative efficacy in terms of performance time, block failure, and the incidence of complications.

Quality assessment

A comprehensive evaluation of the risk of bias for each individual study can be found in Table 2. Out of the included studies, one exhibited a low overall risk of bias, while four studies had some concerns. All studies adequately generated randomized sequences. Although blinding of the block performer and patients was not feasible, the surgeons and assessors responsible for evaluating block-related outcomes were blinded. We found the incidence of block failure and complications demonstrating no significant heterogeneity (I^2 = 0%), whereas we observed moderate heterogeneity for sensory block onset time (I^2 = 68%), motor block onset time (I^2 = 27%), and performance time (I^2 = 95%). With regard to the GRADE assessment for each study, we rated the certainty of evidence for the outcomes of sensory and motor onset time as moderate. For performance time, we deemed the certainty of evidence low due to inconsistency and imprecision. We assigned block failure and complication rates as moderate and high certainty of evidence, respectively.

Discussion

In this meta-analysis, encompassing a total of 5 RCTs and 374 patients, we examined and compared the CCV to ICV approaches in patients undergoing brachial plexus blocks for distal upper extremity surgeries. Our analysis revealed no statistically significant differences between these two techniques with regards to sensory block onset time, motor block onset time, performance time, block failure, and the incidence of complications.

Several authors have hypothesized that CCV could have a faster onset time than ICV due to the fact that the lateral, medial and posterior cords of the brachial plexus are clustered, lateral to the axillary artery, where they can be seen in a single ultrasound window, as opposed to the ICV block, where the cords are scattered around the axillary artery and may not be visible simultaneously.[2,5-7] However, this anatomical difference does not seem to have an impact on this outcome, since sensory and motor block onset times for CCV were found to be comparable to the ICV technique in this meta-analysis. It is unclear why one study (Brown et al.)[15] demonstrated significantly shortened sensory latency with ICV while another (Cesur et al.)[16] found that CCV was faster. This may be related to the different local anesthetic choices and volumes used, since many pharmacokinetic and pharmacodynamic factors may influence onset time of a block. For instance, highly lipid-soluble drugs, like bupivacaine, tend to exhibit slower onset times due to their slower penetration into nerve fibers. On the other hand, less lipid-soluble drugs, such as lidocaine, often offer quicker onset due to their rapid diffusion within the nerve tissue. Apart from drug selection, the volume and concentration chosen also play a pivotal role. Large volumes can

lead to a more extensive spread around the target nerve, increasing the likelihood of achieving a complete block. The concentration of local anesthetic directly affects the rate at which nerve fibers are depolarized, thus influencing the onset time. Higher concentrations of the drug generally induce a faster onset of action due to a more rapid establishment of the nerve block. Nevertheless, the subgroup analysis on different local anesthetics did not change the results which may mean that from a practical perspective, any small difference in mean block onset times is probably clinically irrelevant.

Several authors have proposed that the CCV approach, with its favorable and superficial brachial plexus anatomy and reduced interpatient variability, may result in faster performance times and fewer needle passages.[5,11] However, our findings indicate that there were no statistically significant differences in performance times or in the incidence of block-related complications between the CCV and ICV approaches.

Both the ICV and CCV techniques demonstrated a low rate of complications, consistent with previous reports in the literature.[4,7,22,23] In our meta-analysis, no major complications were reported. Minor complications, such as paresthesia or vascular puncture, occurred in 3.5% (13/374) of all patients, with no statistically significant difference observed between the CCV (1.6%) and ICV (5.4%) groups. Hemi-diaphragmatic paralysis, a concerning complication associated with brachial plexus blocks, was documented in only 2.1% (8/374) of patients in this study, with a similar incidence observed between the CCV (2.1%) and ICV (2.1%) techniques. These finding are consistent with previously published studies in the literature.[7,22,24,25]

In our study, we specifically investigated the incidence of block failure as an additional potential complication, and our findings are consistent with the existing literature. A meta-analysis conducted in 2013 comparing the ICV block to other upper extremity blocks, reported a block failure rate of 11.4%.[3] In various studies, the reported rates of block failure for the CCV block have ranged from 0 to 9%.[4,7,21] In our meta-analysis, we found that 5.1% (19/374) of all blocks experienced failure, requiring the use of rescue blocks or general anesthesia. Importantly, we did not observe any statistically significant differences between the CCV (6.7%–12/189) and the ICV (3.8%–7/185) approaches.

We acknowledge and address the limitations of our study concerning various outcomes. First, the relatively small sample size may have restricted our ability to detect small differences between the groups. However, it is essential to note that our study comprises the largest sample size currently available for comparing these two techniques within high-quality RCTs.

In terms of the primary outcomes of sensory block onset time and motor block onset time, our findings revealed minimal effect sizes in their point estimates (MD -0.16 and -0.12, respectively). However, it is important to note that the wide confidence intervals associated with these estimates do not definitely exclude the possibility of a potentially larger treatment effect.

Another limitation of our analysis is the inability to assess additional outcomes, such as pain scores and patient satisfaction, due to either the absence of these results in the included studies or the unavailability of patient-level-data. The lack of data in these areas restricts our comprehensive understanding of the overall impact of the techniques on pain management and patient experience.

Finally, in terms of heterogeneity, we observed significant heterogeneity ($I^2 > 25\%$) in the outcomes of sensory and motor block onset times. This heterogeneity may be attributed to variations in block techniques employed across the included studies, including differences in anesthetic volume, concentration, and choice of agents (as outlined in Table 1). The diversity in techniques could potentially contribute to the observed heterogeneity and may affect the generalizability of our findings.

Conclusion

This meta-analysis found that the CCV brachial plexus block approach may provide equally fast sensory and motor onset times when compared with the classic ICV approach for adult patients undergoing distal upper extremity surgery, with similar rates of block failure and complications between the two techniques. Although this represents the largest sample size comparing the two strategies, the overall pooled number of patients may still be underpowered for small statistically significant differences between groups. Nevertheless, given the findings of our meta-analysis, if such differences exist, they are unlikely to be clinically meaningful.

Authors' contributions

All authors contributed to the study conception and design. SA and RL performed material preparation, data collection, and analysis. The first draft of the manuscript was written by all authors. All authors critically reviewed previous versions of the manuscript. All authors read and approved the final manuscript. All authors agree to be accountable for all aspects of the work.

PROSPERO registration

CRD42022372297, 14/11/2022.

Conflicts of interest

The authors declare no conflicts of interest.

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Table 1 Baseline characteristics of included studies.

Study	Design	Patients CCV/ICV	Female, CCV/ICV	Age, y CCV/ ICV	ASA I/II/III		BMI CCV/ ICV	LA	Volume of LA in mL	Concentration of LA	Follow-up in days
					CCV	ICV					
Leurcharusmee et al. 2017[13]	RCT	45/45	26/17	41/43	29/15/1	28/14/3	24/23	Lidocaine / Bupivacaine	35	1% / 0.25%	7
Songthamwat et al. 2018[14]	RCT	20/20	11/10	46/49	7/11/2	7/8/5	22/24	Ropivacaine	25	0.5%	7
Brown et al. 2020[15]	RCT	34/30	19/11	49/47	12/18/4	10/15/5	26/28	Ropivacaine	35	0.5%	7
Cesur et al. 021[16]	RCT	40/40	19/22	36/34	7/31/2	7/31/2	23/24	Lidocaine / Bupivacaine	25	1% / 0.25%	1
Dost et al 2021[17]	RCT	50/50	8/9	40/41	38/12/0	29/21/0	25/27	Bupivacaine	20	0.5%	7

Age, mean; BMI, Body Mass Index in $kg.m^{-2}$ (median); LA, Local Anesthetic.

Table 2 Risk of bias summary for randomized studies (RoB 2).

	D1	D2	D3	D4	D5	Overall
Leurcharusmee et al. 2017	⊕	⊖	⊕	⊕	⊕	⊖
Songthamwat et al. 2018	⊕	⊕	⊕	⊕	⊕	⊕
Brown et al. 2020	⊕	⊖	⊕	⊕	⊕	⊖
Cesur et al. 2021	⊕	⊖	⊕	⊕	⊕	⊖
Dost et al. 2021	⊕	⊖	⊕	⊕	⊖	⊖

Judgement: ⊕ Some concerns; ⊖ Low risk.
Domains:

D1: Bias arising from the randomization process.

D2: Bias due to deviations from intended intervention.

D3: Bias due to missing outcome data.

D4: Bias in measurement of the outcome.

D5: Bias in selection of the reported result.

Figure 1 Schematic representation showing the relationship of the cords of the brachial plexus to the axillary artery on the infraclavicular (A) and costoclavicular (B) approaches. AA, Axillary Artery; AV, Axillary Vein; LC, Lateral Cord; MC, Medial Cord, PC, Posterior Cord; PMj, Pectoralis Major Muscle; PMn, Pectoralis Minor Muscle; SC, Subclavius Muscle; AS, Anterior Serratus Muscle.

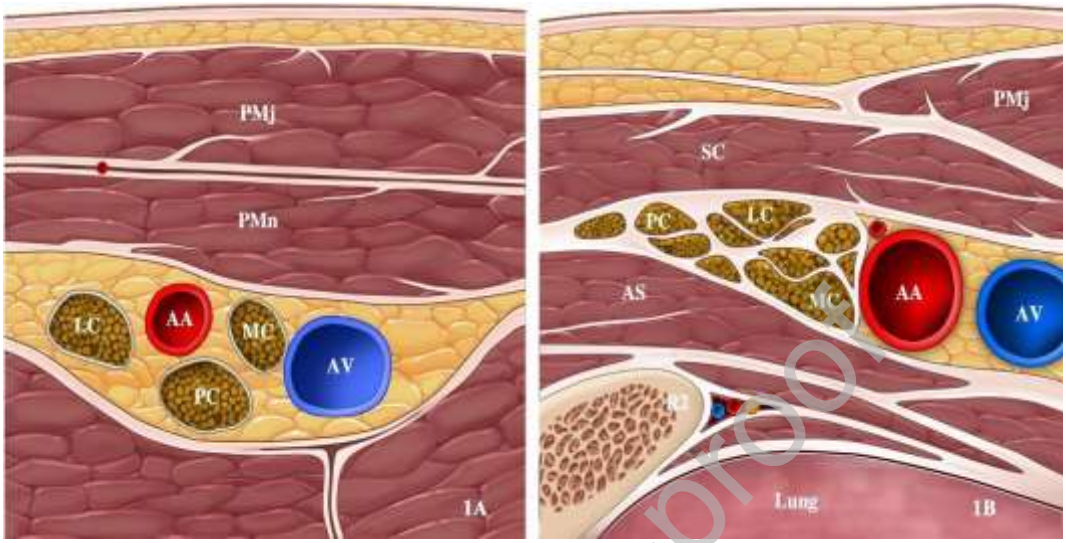


Figure 2 PRISMA flow diagram of study screening and selection.

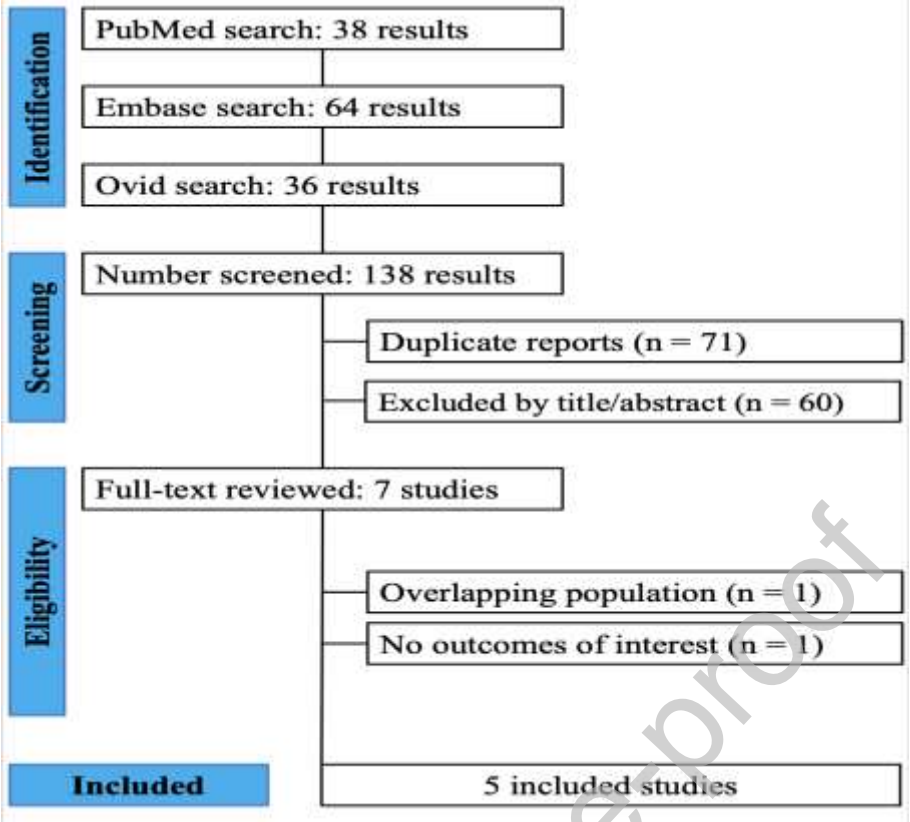
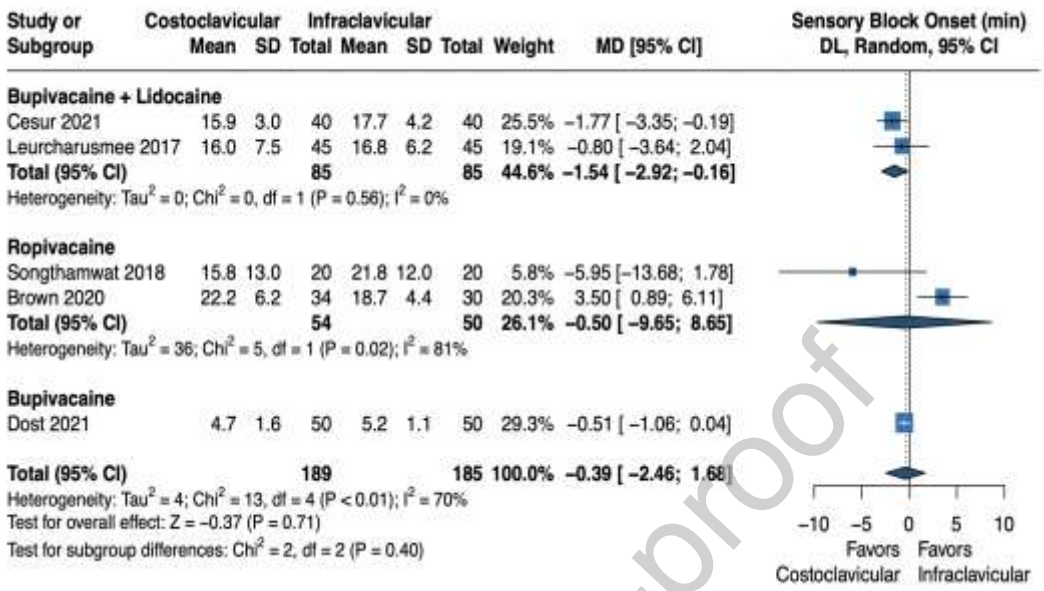


Figure 3 Sensory Block (A) and Motor Block (B) Onset Times were not statistically significantly different between the CCV and ICV approaches even when subgroup analysis considering different local anesthetics administered was performed.

3A



3B

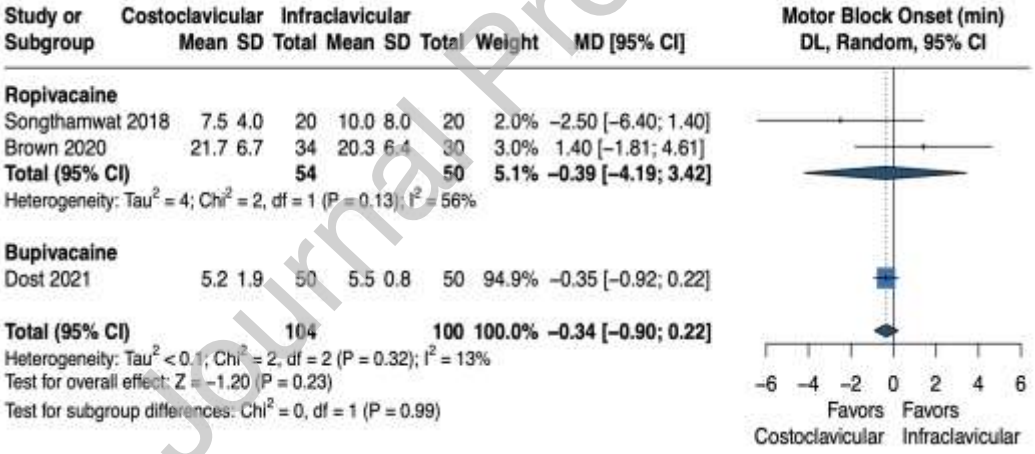


Figure 4 There was no statistically significant difference in performance time of CCV and ICV blocks.