Supraclavicular vs. Infraclavicular Brachial Plexus Nerve Blocks: Clinical, Pharmacological, and Anatomical Considerations

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Abstract

Peripheral nerve blocks (PNB) have become standard of care for enhanced recovery pathways after surgery. For brachial plexus delivery of anesthesia, both supraclavicular (SC) and infraclavicular (IC) approaches have been shown to require less supplemental anesthesia, are performed more rapidly, have quicker onset time, and have lower rates of complications than other approaches (axillary, interscalene, etc.). Ultrasound-guidance is commonly utilized to improve outcomes, limit the need for deep sedation or general anesthesia, and reduce procedural complications. Given the SC and IC approaches are the most common approaches for brachial plexus blocks, the differences between the two have been critically evaluated in the present manuscript. Various studies have demonstrated slight favorability towards the IC approach from the standpoint of complications and safety. Two prospective RCTs found a higher incidence of complications in the SC approach – particularly Horner syndrome. The IC method appears to support a greater block distribution as well. Overall, both SC and IC brachial plexus nerve block approaches are the most effective and safe approaches, particularly under ultrasound-guidance. Given the success of the supraclavicular and infraclavicular blocks, these techniques are an important skill set for the anesthesiologist for intraoperative anesthesia and postoperative analgesia.

Keywords: Supraclavicular, Infraclavicular, Peripheral Nerve Blocks, Brachial Plexus, Ultrasound-Guided, Regional Anesthesia

1. Context

There has been a remarkable resurgence of regional anesthesia, especially peripheral nerve blocks (PNB), with widespread implementation of these in enhanced recovery pathways after surgery and pain management (1, 2). Although, opioids are the cornerstone analgesics for perioperative pain relief, regional anesthesia has ameliorated postoperative pain, decreased opioid consumptions, and their potential complications (3-8). Furthermore, some peripheral nerve entrapments and surgical conditions can be successfully treated by peripheral nerve blocks (9-12). The use of adjuvant agents for pain relief and peripheral nerve blocks (by single injection, and continuous infusion) are a popular practice to reduce the reliance on opioids during perioperative pain management (13-17).

Surface landmarks were used earlier to perform PNB. Nerve stimulation and ultrasound guidance are commonly used now for localization of the nerves and to deposit local anesthetic solutions around neural tissue (18, 19). The development and introduction of the portable nerve stimulator to clinical practice was a critical advance in regional anesthesia. The advent of ultrasound, better needles, catheter systems, and monitoring has further rejuvenated the practice of regional anesthesia.

Ultrasound guidance for nerve blocks is rapidly emerging as a standard of care with the availability of less expensive portable high-resolution ultrasound systems. Ultrasound guidance aids in real-time visualization of the needle and the relevant anatomy (e.g. brachial plexus blocks) (20, 21). When compared to nerve stimulation, ultrasound guidance for brachial plexus block has been shown to im-

prove efficiency and block success, reduce complications like vascular puncture and local anesthetic systemic toxicity (22). The use of ultrasound has also resulted in faster block performance time and onset time (23). Increasing use of PNB in the ambulatory surgery setting has improved postoperative pain control and has resulted in faster recovery (24).

In 1994, Kapral and colleagues studied ultrasound guided for supraclavicular block and its effect on the success rate and incidence of side effects in 40 cases undergoing surgery of the hand and forearm (25). Since then, there have been numerous contributions from all over the world to improve the application of ultrasound imaging in regional anesthesia

A survey in 2012 indicated peripheral nerve blockade by ultra-sound guidance are generally trained across anesthesia educational plans, and the initial obstacles to ultrasonography use were deficit of teaching faculty training and proper accessibility of devices (26). Comprehensive education of anatomy and adequate pre-scanning, and instrument arrangement, is a prerequisite for a successful USG guided PNB. Appropriate use of depth, frequency, focal zones, and gray-scale mapping will provide the clearest view of the target nerve/plexus (27). A high-frequency, broadband, linear probe would be appropriate for commonly performed upper extremity PNBs.

Upper extremity anesthesia can be established by blocking the brachial plexus along its course (trunk, divisions, cords, branches) from the spinal cord (28). Brachial plexus block was first performed with cocaine, under direct exposure in the neck. In 1911, the first percutaneous brachial plexus block was described (29). These publications were followed by many others.

Depending on the approach and the location of the blockade, generally performed brachial plexus blocks are axillary, infraclavicular, supraclavicular, and interscalene. Each approach has its own complexities and advantages. It is imperative that the provider is aware of these characteristics for the successful performance of the block. This review will focus on the infraclavicular and supraclavicular nerve blocks.

2. Infraclavicular Block

The infraclavicular approach targets the brachial plexus at the level of the cords, which are in close proximity to the first and second part of the axillary artery. It provides excellent anesthesia for procedures of the hand, wrist, forearm, and elbow. The advantages of the infraclavicular block are that it usually results in a near-complete blockade of the brachial plexus, provides stability for

catheter placement. There is also no need for manipulation of the arm for performing the block (30-32). The disadvantages are that the infraclavicular block is a deeper block, sometimes necessitating the needle or probe, along with steep angles of needle insertion that result in needle tip visibility issues.

Multiple infraclavicular peripheral blocks (ICPB) have been explained by several needle surface landmarks, insertion points, and directions. The first infraclavicular approach to brachial plexus block was described in 1917. Trans-pectoral perivascular approach for infraclavicular was described by Speigel in 1967 (33). Raj's modification involved directing the needle laterally and thus reducing the risk of pneumothorax which was could be seen in Labat's technique. He also reported higher success rates of the blocks using a nerve stimulator (31). Numerous modifications have been described, and it is impossible to cover each one in this paper. The different approaches can be broadly classified into proximal or distal with regard to at the axillary artery, that is, "proximal ICPB" if the local anesthetic is injected at its first portion and "distal ICPB" for the injection at its second portion (and further) (34). Examples of proximal ICPB include vertical proximal approach as described by Kilka et al. (35), lateral proximal approach (lateral-to-medial needle direction) as described by Li et al. (36) (costoclavicular approach) and Yoshida et al. (37), and medial proximal approach (medial-to-lateral needle direction) by Nieuwveld et al. (medial approach) (38). The Raj et al.'s approach, the coracoid approach by Whiffler, and the lateral sagittal infraclavicular block described by Klaastad et al. fall into the category of "distal ICPB" (31, 39, 40).

A total of 30 - 40 mL of the local anesthetic solution is commonly used, taking into consideration the toxic dose. All methods need either an ultrasound or nerve stimulator to recognize the nerves. In 50 % of patients, the musculocutaneous nerve and the axillary nerve leave the sheath before the coracoid process, and therefore contraction of the biceps or deltoid may not result in a successful block. The better predictors for a successful block are wrist or fingers extension (radial nerve stimulation), or to a lesser extent, their flexion (median nerve stimulation) (41, 42).

During localization of the infraclavicular structures by ultrasound guidance, the plexus can be found between the coracoid process and the middle of the clavicle. A linear (high-frequency) ultrasound probe is commonly used, although some practitioners prefer a small curve array probe. It is not mandatory to visualize the plexus for every block. Formation of a crescent of local anesthetic both all sides and posterior to the axillary artery often obtains a trusty block. The plexus is simply block side by side the coracoid process using ultrasonography compare to medial to the vertical ICPB site. The best visualization can be

obtained by the probe at the parasagittal approach, only medial to the coracoid process, and only caudal to the clavicle. The artery is commonly simply visible deep to the pectoralis minor muscle. The nerve with hyperechoic feature are often detected at upper (lateral cord), posterior (posterior cord), and lower (medial cord) location to the artery. The needle is inserted in the parasagittal level and directed behind to the artery. Injectable solution is best put in a horseshoe among 3 and 11 o'clock (43, 44).

In 2004, Klaastad used MRI models to test an infraclavicular block that was performed by the lateral sagittal direction (lateral sagittal infraclavicular block [LSIB]). The needle is inserted at the junction among the clavicle and the coracoid process. The needle is conducted 0°-30° posterior, exactly in the sagittal plane besides the coracoid process while adjacent the antero-inferior border of the clavicle (40). Though Klaastad's technique was initially adopted to be used with nerve stimulation, it is more commonly performed now with ultrasound guidance. In 2017, Li et al. (36) described a new technique called the costoclavicular brachial plexus block. This approach tries to overcome some of the limitations of LSIB. These limitations are that, namely, the cords of the brachial plexus are placed at a depth (3 - 6 cm), they are apart from one another, there is remarkable difference in the location of the particular cords comparative to the axillary artery, and all three cords are seldom detected in a single ultrasonographic view. The costoclavicular space (CCS) is the intermuscular space positioned deep and behind to the middle point of the clavicle and among the clavicular head of the pectoralis major and subclavius muscle anteriorly and the 2nd rib posteriorly. The advantage suggested at the CCS is the cords are gathered with each other lateral to the axillary artery with a constant correlation to one another. A local anesthetic single shot with a lower volume can be administered with an effective block. Using this method, a transverse scan is done beneath the middle point of the clavicle and upon the medial infraclavicular fossa with the transducer angled cephalad, causing a view with all three visible cords. The needle is conducted in-plane in a lateral to medial orientation (36). In a published paper by Songthamwat et al., the costoclavicular method had a more rapid onset for sensory block and more quick preparation for surgical operation compare to the LSIB method (45).

3. Supraclavicular Block

The supraclavicular nerve block of the brachial plexus has become one of the more commonly used blocks for upper extremity surgery as it consistently provides reliable regional anesthesia. For this reason, it is commonly referred to as the "spinal of the arm" (46).

The brachial plexus is consisted by the ventral rami of C5-T1. These nerve roots subsequently divide into trunks, divisions, cords, and branches. The supraclavicular block targets the distal trunk/proximal division level of the plexus. At this level, the plexus is compact, which allows for local anesthetic to influence a maximal number of nerves (46).

Technique for the supraclavicular block has evolved over time. Originally this was a landmark-based technique that used paresthesia to confirm proper needle placement. The block needle is conducted at the junction of the superior edge of the clavicle and lateral aspect of the sternocleidomastoid muscle aiming towards the first rib. Cranial and caudal needle adjustments are made in small increments in the same sagittal plane as needle entry until contact with the plexus is achieved. Proper needle placement is confirmed by paresthesia experienced by the patient (46). This "blind" technique was originally accompanied by a more risk of side effects such as intravascular injection, pneumothorax, and phrenic nerve block, Horner syndrome, and block failure (47). In addition, this technique can require multiple trial and error needle sticks and adjustments, leading to increased patient discomfort and procedure time (48).

For locating peripheral nerves by using peripheral nerve stimulator, an insulated needle is used to produce a short-duration low-intensity electric current to elicit a muscle twitch or sensation when in close proximity to the nerves. This response confirms accurate needle placement and allows for local anesthetic spread in the desired location. The benefit of this technique is that the practitioner can manipulate the needle to elicit a response in specific muscle groups to achieve the desired block. Despite increased confidence in needle placement, this technique did not reduce the risk of injury to surrounding structures (47).

The use of ultrasound in supraclavicular blocks allowed for the possibility of decreased risk and improved blockade with the visualization of real-time images. In the beginning, ultra-sound guided supraclavicular blocks was performed by an in-plane approach, typically from lateral to medial. The ultrasound is first used to identify the brachial plexus, which can be recognized as a cluster of hyperechoic spots surrounded by hypoechoic areas, often referred to as a "bunch of grapes". This will be seen above the first rib and pleura, lateral and superficial to the subclavian artery. This makes the subclavian artery a valuable landmark in identifying the plexus. In addition, it is advisable to keep the artery in view during the block to avoid unintended vascular injury. Once identified, the needle is advanced in the plane so the tip can be visualized as it approaches the plexus. There are many recommendations as

to where to deposit the local anesthetic. In general, the needle should be directed to ensure the entire plexus is surrounded by local anesthetic for best results (46). Ultrasound provides the benefit of visualizing local anesthetic spread. It has been theorized that this allows for a lower amount of local anesthetic needed for adequate blockade. However, ultrasound-guided supraclavicular blocks have not been proven to require less local anesthetic, and further research is needed (49). In comparison to the peripheral nerve stimulator technique, ultrasound guidance likely has the advantage of a more comfortable block given the need for fewer trial-and-error sticks, direct visualization of structures, and no nerve stimulation. A randomized control trial by Alfred et al. demonstrated a shorter procedure time and onset of motor and sensory blocks, along with increased duration of sensory block in supraclavicular block under ultrasound guidance compared to the nerve stimulator technique (47).

The increased safety and success afforded to supraclavicular blocks by ultrasound guidance has led to the resurgence and popularity of their use in upper extremity surgery. Studies have demonstrated decreased incidence of pneumothorax and vascular injury with ultrasound guidance (50). A retrospective review of US-guided supraclavicular blocks reported incidence rates of 1% or less for complications including unilateral diaphragmatic paresis, Horner syndrome, inadvertent vascular puncture, and temporary sensory deficits. Additionally, the same study highlighted the high success rate of these blocks with a 94.7% successful block on the first attempt (51). Gamo et al. demonstrated the US-guided supraclavicular block provided adequate intraoperative conditions for an average surgical duration about more than one hour. Additionally, they reported an average of 437 minutes of postoperative analgesia (52). Various reviews have continued to validate the success of the supraclavicular block in providing reliable regional anesthesia to the upper limb.

4. Comparison of Safety and Efficacy of Supraclavicular vs. Infraclavicular Approaches

Several studies have compared variables regarding the safety and efficacy of the various block approaches – such as procedural time, the onset of surgical anesthesia, procedure-related pain, procedural complications, distribution of anesthesia/analgesia achieved, and need for supplemental anesthesia.

4.1. Safety of Brachial Plexus Nerve Blocks

The literature on the efficacy of different block approaches supports the use of the supraclavicular block (SC)

and infraclavicular block (IC) approach compared to other methods with regards to both safety and efficacy. A randomized, observer-blinded study with 60 patients evenly divided into three groups examined the SC, IC, and interscalene (IS) approaches and found that the IS approach had a longer onset time to anesthesia compared to either the IC or SC approaches. Additionally, out of the 20 patients in the IS group, two of them experienced phrenic nerve palsy as a complication. No other significant differences in measured outcomes were noted. Given the rate of phrenic nerve palsy in the IS method, the SC and IC approaches are preferred (53). Another prospective randomized controlled trial (RCT) compared ultrasound-guided SC, IC, and axillary blocks in 120 patients divided evenly into three groups and determined that all three approaches had similar rates of success in achieving surgical anesthesia and similar pain-related scores. However, it was noted that the axillary group required a higher number of needles passes in addition to having a longer total-anesthesia-related time (sum of procedural time and onset of anesthesia time), making the SC and IC approaches more ideal for upper extremity blocks (54).

A feared complication of brachial plexus blocks is pneumothorax (PTX) due to the anatomic proximity of the pleura. The use of US-guidance greatly minimizes the risk of PTX. A prospective observational study examined the risk of developing PTX in ultrasound-guided periclavicular blocks, where the IC approach was used in 2,963 and the SC in 3403 patients. In this study, clinically symptomatic PTX occurred in four cases-two in the IC group and two in the SC group. Compared to previous data on brachial plexus blocks not using US-guidance, the comparative incidence was 0.06% in this study compared to 6.1% without US-guidance, a statistically significant reduction in risk for PTX (55).

The SC and IC approach appear to be clinically safe for use and are the preferred method in pediatric populations as well. A randomized trial compared success rates, complications, block duration, and performance time of ultrasound-guided SC versus IC blocks in 80 children ages 5-15 and found both approaches to be effective and safe for children. In this trial, 88% of IC patients achieved surgical anesthesia without supplemental analgesia compared to 85% in the SC group. It was noted that the SC block had a faster performance time compared to the IC group (9 minutes vs. 13 min) (56).

Given the SC and IC approaches are the most common approaches for brachial plexus blocks, the differences between the two have been examined. Various studies have demonstrated slight favorability towards the IC approach from the standpoint of complications and safety. Two prospective RCTs found a higher incidence of com-

plications in the SC approach – particularly Horner syndrome (54, 57). Additionally, a systematic review of 10 RCTs found a greater incidence of procedural complications in the SC approach compared to the IC approach. However, the SC approach still had fewer complications than any other approach besides IC. The complications included paresthesia, injection pain related to the procedure, phrenic nerve palsy, and once more Horner syndrome (58). One randomized trial additionally found patients who received SC blocks reported higher incidence of postoperative sleep disturbances relative to those who received the IC approach (59). Other RCTs have also illustrated a lower incidence of required supplemental anesthesia or subsequent block administration – thus reducing the incidence of procedural-related pain or paresthesia and reducing the number of required needle passes (57, 60, 61).

Overall, from the perspective of procedural safety of brachial plexus nerve blocks, the SC and IC are both viable approaches when compared to other approaches such as axillary or IS blocks. Regardless of approach, US-guidance greatly reduces the incidence of complications, including vascular puncture, pneumothorax, and the need for subsequent block. Between the SC and IC approaches, the SC approach is associated with a higher incidence of complications, including paresthesia, procedural pain, phrenic nerve palsy, and most commonly Horner's syndrome – making the IC the preferred approach.

4.2. Efficacy of Brachial Plexus Nerve Blocks

Supraclavicular and infraclavicular brachial plexus blocks are the two most clinically effective approaches to achieving upper extremity surgical anesthesia. SC and IC require less supplemental anesthesia, are performed more rapidly, have quicker onset time, and have lower rates of complications than other approaches (axillary, interscalene, etc.) (53, 54).

Regarding efficacy between the two approaches, the literature appears less clear on which achieves better outcomes in terms of anesthesia – though the IC method appears to be associated with fewer complications. An RCT of 80 patients examined Ultrasound-guided SC, and IC approaches for sensory and motor blocks, performance time, and quality of anesthesia achieved. It was determined that both methods achieved similar performance time and procedural-related pain scores. The study did find a significant difference in supplementation rate, when required, for the radial territory (18% in the IC group vs. 0% in the SC group). Overall, however, it was determined that both approaches were able to produce a similar degree of surgical anesthesia without supplementation in the majority of cases (62).

Two other RCTs examined the SC vs. IC approaches. One study particularly utilized perineural catheters for ultrasound-guided bolus delivery of anesthesia. In this study, 88% of SC patients and 100% of IC patients achieved sensory block within 30 minutes with no significant differences in the time to complete the procedure. It was thus determined that both approaches provided an optimal block with no true significant differences between the approaches (59). In the second trial, 150 patients split into two groups (SC vs. IC) were given ropivacaine ultrasound-guided blocks, and the mean procedural time, sensory block achieved, and failure rate were similar. The only difference noted was a lower incidence of paresthesia in the IC group (60).

Both block approaches have also been supported for use in pediatric populations. The studies concluded both SC and IC approaches achieve a sufficient degree of analgesia for upper extremity procedures. In a randomized trial of 80 children receiving SC or IC blocks (n = 40 and n = 40, respectively), 88% of IC patients achieved surgical anesthesia without supplemental oral analgesia compared to 85% in the SC group. The SC approach was performed more quickly on average in this trial, although it had a higher degree of suboptimal ulnar sensory block. Otherwise, they were both found to be effective approaches and similar in other outcomes measured (56). A retrospective analysis additionally confirmed similar outcomes for both approaches in pediatric patients. Block procedural time was similar in both, 9.54 ± 2.14 minutes for the SC group and 12.9 ± 2.8 minutes for the IC group. The mean block time for the SC group was 7.5 ± 2 hours and 7.4 ± 1.5 hours in the IC group. No complications were noted, and both were deemed effective and safe for pediatric patients (63).

In various other trials, however, the efficacy of the IC approach appears to be more favorable. An RCT of 120 patients compared SC vs. IC block performance times, efficacy, and complications. In this trial, sensory scores were assessed in seven terminal nerves every 10 minutes until surgical anesthesia was achieved. Patients in the IC group achieved faster onset of anesthesia with greater block efficacy than in the SC group. The SC group demonstrated a better block of the axillary distribution. However, the IC group had a better block of both median and ulnar nerve distributions. Ultimately, the findings supported IC being the faster onset, higher efficacy group with lower incidence of complications. Procedural performance time was not significantly different in this study (64).

In a randomized trial of 60 patients, both SC and IC approaches were compared to continuous peripheral nerve blocks with an ultrasound-guided catheter placement technique. Patients in the IC group had an average pain median of 2. SC group reported a median of 4. The IC

group required less overall supplemental oral analgesia as well. Additionally, post-op day one pain scores were examined – the IC group demonstrated lower pain levels in this outcome as well (0.5 vs. 2.0). Thus, in a perineural catheter block, the IC approach was preferred to achieve local anesthesia (61).

The IC method appears to support a greater block distribution as well. In a prospective RCT comparing the various approaches, complete sensory blockade was measured. The trial found complete sensory blockade to be achieved in 57% of patients receiving an SC approach, while 70% in the IC group. The difference was primarily attributed to the SC method being unable to achieve a full ulnar distribution block, whereas the IC approach could (65). A systematic review further supports these outcomes, noting a higher incidence of complete block in the ulnar distribution across ten randomized trials – though did not find differences in block time, rate of performance, or time of onset. However, it was concluded that the IC approach is preferred due to a significantly lower incidence of complications relative to the SC approach (58).

Overall, both SC and IC brachial plexus nerve block approaches are most effective and safe approaches – particularly under ultrasound-guidance. The literature regarding the differences between the two approaches generally demonstrates similar outcomes regarding both in terms of block onset time, procedural performance, and duration of block. However, there is evidence favoring the IC approach due to a more complete block distribution, less need for supplemental oral analgesia, and lower incidence of complications – including procedural-related pain, Horner's syndrome, and vascular puncture. Table 1 lists the studies discussed comparing the IC, and SC approaches.

5. Conclusions

Both the supraclavicular and infraclavicular block are consistently and reliably used for regional anesthesia to the upper limb. As seen, studies have supported their similar performance time, procedural-related pain scores, and block success. In addition, they have been shown to be more effective in various ways, including quicker procedure time, less supplemental anesthesia, faster onset, and fewer complications when compared to other brachial plexus blocks (66,67). The superior safety of these blocks compared to other brachial plexus blocks has been demonstrated, especially with the use of ultrasound guidance. Their use has not been restricted to adults as their safety and efficacy have also been demonstrated in the pediatric population. Given the success of the supraclavicular and infraclavicular blocks, these procedures are an important

skill set for the anesthesiologist. In choosing between the two approaches often the clinician's comfort level and training may dictate the choice. However, there are other factors that can be considered. As discussed in comparing the supraclavicular and infraclavicular approaches, some studies have demonstrated a faster onset, lower incidence of complications, and reduced need for supplemental analgesia with infraclavicular blocks. Additionally, studies support a greater block distribution with the infraclavicular approach, especially concerning the ulnar distribution. All things considered, both blocks can provide reliable anesthesia however there are several advantages to the infraclavicular block. As always clinicians should assess the specific needs of the patient when deciding between these two approaches.

Footnotes

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Table 1. Comparison of Supraclavicular Versus Infraclavicular Approaches

Reference number	Groups Studied and Intervention	Results and Findings	Conclusions
Bharti et al. (53)	Randomized, observer-blinded study of 60 patients split into 3 groups comparing ease of performance and surgical efficacy of USG nerve block approaches. Assessed block efficiency time, success rate, duration of block and post-op pain relief and block performance time of the different approaches.	Three groups were supraclavicular (SC), infraclavicular (IC), and interscalene (IS). Onset time was longer with IS group. No differences in imaging time/block performance. Pain scores/success rates and post-op analgesia were same. Two patients in IS group developed phrenic nerve palsy.	IS block below C6 nerve root has longer onset time than SC and IC approach, and has unsuitable cases of phrenic nerve palsy. Thus, other two approaches are preferred.
Arcand et al. (62)	Randomized prospective study of 80 patients split into two groups examining USG SC and IC blocks. Hypothesized that performance time and quality of IC approach is similar to SC.	Sensory and motor block, and supplementation rate assessed. Only significant difference was supplementation rate for radial nerve distribution, where IC group had 18% supplementation rate and 0% in SC. Performance times were not significantly different and technique pain scores were same.	USG IC block is at least as rapidly performed as SC approach and produces similar degree of surgical anesthesia without supplementation.
De José María et al. (56)	Randomized trial that compared success rate, complications, and performance time of USG SC vs IC brachial plexus block in 80 children 5-15 divided into two groups. Block duration and volumes were measured.	IC group 88% achieved surgical anesthesia without supplemental analgesia compared to 85% in SC group. Failures in group IC were due to arterial puncture and suboptimal radial sensory block. Failure in SC group were due to suboptimal ulnar sensory block. IC group performance time was 13 min avg and SC was 9 min (significantly different).	Both approaches are effective in children and safe. No major complications were noted. The SC approach was faster to perform.
Koscielniak-Nielsen et al. (64)	Randomized study of 120 patients divided into two groups comparing USG SC vs. IC block performance and onset times, efficacy, and complications. Hypothesized SC approach to be effective and overall better since it is more superficial and easier to visualize with US.	Sensory scores of seven terminal nerves were assessed every 10 minutes until block was achieved and deemed effective for surgery. Significantly more patients in IC group were ready in 20-30 min with a block performance time of 5.7 min versus S group 5.0 min. Block efficacy greater in IC group than SC (93% vs 78%). SC group had superior block of axillary nerve but insignificant median and ulnar nerves block.	IC block has faster onset, better efficacy, and less adverse events than SC approach. Block time and patients' acceptance of procedure were not significantly different.
Harrison et al. (59)	RCT comparing efficacy of SC vs. IC perineural catheters for USG through-catheter bolus anesthesia. 50 patients randomly assigned to two groups (SC and IC). Primary measurement was time to achieve complete sensory block in ulnar and median distribution. The second measurement outcomes were procedure time, pain, side effects, post-op pain, and weakness.	All but 2 perineural catheters were placed successfully. 21/24 (88%) SC patients and 24/24 (100%) IC patients achieved complete sensory block by 30 minutes with no significant difference in time to achieve the complete anesthesia. SC group showed more post-op sleep disturbances.	Both SC and IC perineural catheters using a through-catheter bolus of anesthesia provided effective block with no true significant difference between the two approaches. They are both effective in achieving brachial plexus anesthesia.
Mariano et al. (61)	RCT of 60 patients comparing efficacy of IC vs SC continuous peripheral nerve blocks for post-op analgesia. Split 31 (IC) and 29 (SC), pre-op patients received brachial plexus blocks via USG IC or SC catheter technique. Post-op, subjects discharged with anesthetic pumps with primary outcome measured as average pain score on day after surgical procedure.	Subjects in IC group showed average pain median of 2. SC group reported median of 4.0 (10th – 90th percentiles 0.6-7.7). Additionally, post-op day 1 scores were lower in the IC group relative to the SC group with least pain scores being 0.5 vs. 2.0, respectively. IC group also required less supplemental oral analgesia.	IC perineural catheter approach provides more effective analgesia compared to the SC approach.
Tran et al. (54)	Prospective, observer-blinded RCT that compared USG SC, IC, and axillary blocks of the brachial plexus in UE surgery. 120 patients evenly divided into SC, IC, and axillary groups. Assessed block performance time, pain scores, success rate, and complications. Main consequence was total anesthesia time – defined as sum between procedure performance and onset times.	No statistically significant differences noted in total anesthesia time, success rate, pain scores, paresthesia, or vascular complications. The axillary group required higher number of total needles passes relative to other two approaches along with longer overall performance time. SC blocks resulted in increased rate of Horner syndrome.	USG brachial plexus blocks using SC, IC, and axillary approaches had similar success rates. However, axillary approach takes longer and requires more needle passes. SC approach results in higher incidence of Horner syndrome as a complication.

Fredrickson et al. (65)	Prospective, observer blinded RCT of 60 patients comparing onset time of anesthesia in brachial plexus blocks. SC approach was injected into 'corner pocket' inferolateral/lateral to subclavian artery. IC approach was a triple point injection placed all sides of axillary artery. Assessed onset time of block and need for supplementation.	Mean onset time in of blockade in all distributions was determined to be similar in both groups, with SC approach being 22 min and IC group 21 min. Complete sensory blockade was fully achieved in 57% of SC group and 70% of IC group both by 30 min. 11 failures occurred with SC approach due to incomplete ulnar blockade.	Onset of block times is similar in both approaches; however surgical anesthesia was more optimal in IC group due to more complete block of the ulnar distribution compared to SC.
Yazer et al. (57)	Prospective RCT comparing USG intracluster injection using SC approach vs. IC approach of the brachial plexus. 64 patients randomly divided into two groups using same anesthetic agent (lidocaine 1.5% w/epi). Performance time, rate of needle passes, pain during procedure, and side effects were assessed. Main outcome was total anesthesia time.	No differences were observed in success rate, block-related pain scores, or complications such as abnormal paresthesia or vascular punctures. The total anesthesia-related time was shorter in the SC group (8.9 min vs. 17.6) due to more rapid onset. IC group required less needle passes (2 vs. 6) and shorter performance time. There was also a decreased incidence of Horner syndrome as a complication in the IC group.	Both approaches have a comparable success rate. SC approach results in shorter total-anesthesia related time due to more rapid onset. However, SC approach has much higher incidence of Horner syndrome.
Gauss et al. (55)	Prospective observational study on risk of PTX in USG periclavicular brachial plexus nerve blocks. 2963 IC approach blocks, and 3403 SC blocks were performed under US guidance.	PTX occurred in four cases, two in the IC group and two in the SC group. All cases relieved via chest tube. PTX risk is reduced compared to reported incidence when not using US monitoring (up to 6.1% vs. 0.06% in this study). Additionally, all PTX cases were performed by anesthesiologists who performed fewer than 20 blocks previously.	Feared complication of brachial plexus nerve blocks includes pneumothorax given anatomic proximity of the pleura. US-guidance significantly reduces risk.
Dhir et al. (60)	Prospective, observer-blinded RCT comparing efficacy of SC and IC block approaches for elbow surgery. Ropivacaine USG brachial plexus blocks given to 150 patients divided into 2 groups for SC and IC block. Assessed performance and sensory block onset time. Also, surgical anesthesia, procedural pain, motor block, axillary block, and ulnar sparing were assessed.	Similar mean block procedure time in both groups – 285 (+/- 128) seconds in IC and 307 (+/- 138) seconds in SC. Sensory block onset in both groups was similar.	Both blocks equally effective for surgical elbow procedures. Block onset time, procedure time, and failure rate were similar in both groups. Lower incidence of paresthesia in IC group.
Park et al. (58)	Systematic review assessing RCTs that assessed SC vs IC brachial plexus block of 4 peripheral branches. Primary outcome was incidences of incomplete sensory block. Secondary outcomes were successful blockade incidence, performance time, duration of analgesia, complications, and onset time of block. 10 RCTs with 676 patients were assessed.	Partial block at 30 minutes in radial nerve distribution was greater in the IC group, which favored SC group in this case. However, the reverse was true in the ulnar distribution (IC had lower incidence). No differences in secondary outcomes were really noted. Complications of paresthesia, injection pain, phrenic nerve palsy, and Horner's was notably more in SC group.	IC approach demonstrates higher rates of incomplete block in radial distribution, but lower incidence than SC in ulnar distribution – particularly with multiple injection technique. Similar outcomes in successful overall block rate, time, and onset. More complications in SC approach.
Altinay et al. (63)	Retrospective review of data on pediatric patients who underwent USG brachial plexus blocks between 2015-2017. 24 total patients, 15 underwent SCB approach and 9 in the ICB approach. Mean age of 9.6 years.	Mean duration of 9.54 minutes for SC block and 12.9 minutes for IC block. Mean block time was similar in both SCB and ICB, 7.5 hours vs. 7.4 hours, respectively. No complications.	Both approaches safe and effective in pediatric population.