

Motor-Sparing Surgical Nerve Blocks for Upper Extremity Surgery: Significantly Less Motor Paralysis Using 15 mL versus 30 mL of Mepivacaine 1.5% for Supraclavicular Block - A Prospective Randomized Double-Blinded Study

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Received date: February 03, 2017; Accepted date: April 05, 2017; Published date: April 18, 2017

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Abstract

Background and objectives: We performed a prospective randomized double-blinded study evaluating if a reduced volume of local anesthetic would result in operative limb surgical anesthesia while decreasing motor paralysis during an ultrasound-guided supraclavicular nerve block. Current tendencies in clinical practice towards smaller injectate volumes during ultrasound-guided nerve block placement prompted our investigation on its impact regarding block quality.

Methods: 43 patients were consented for this prospective, double-blinded randomized clinical trial. Each patient was randomly assigned. Group HIGH received the conventional injection dose of 30 mL of 1.5% Mepivacaine. Group LOW received the reduced volume dose of 15 mL. An ultrasound-guided supraclavicular nerve block was performed on each patient. Motor block and sensory perception to pin-prick were assessed in the nerve distributions for the ulnar, median, radial, and musculocutaneous branches at 5, 10, 15, 20, and 30 minutes post-injection.

Results: Complete motor block in the radial, ulnar, musculocutaneous and median nerve distributions at 30 minutes, was present in 55% of patients in Group HIGH versus 10% in Group LOW and was statistically significant between both groups ($p < 0.01$). The anatomic distribution of the observed motor-sparing was statistically significant in the median ($p < 0.01$) and ulnar ($p < 0.05$) nerve branches among those patients who received 15 mL LA boluses.

Conclusions: Our study demonstrated that 15 mL vs. 30 mL injections of mepivacaine 1.5% at the supraclavicular approach provide equivalent surgical anesthesia, while reducing the incidence of motor block. These findings may have implications on early postoperative physical therapy for the subset of patients that present with Galeazzi-type fractures, carpal tunnel syndrome, and minimally-displaced distal radius fractures.

Keywords: Regional anesthesia; Upper extremity surgery; Surgical block; Supraclavicular block; Motor-sparing; Local anesthetics

Introduction

Recent minimum effective volume studies for the supraclavicular block have demonstrated that 32 to 42 mL of local anesthetic are required to achieve successful blockade in at least 90% of patients [1,2]. Other investigators have also reported similar rates of successful blockade with much smaller volumes, ranging from 10 to 20 mL [3-5]. In a study by Bertini et al., motor block duration from regional anesthesia was more a consequence of local anesthetic volume as opposed to dose [6]. Immediate postoperative physical therapy protocols, requiring patient mobility, have been shown to improve functional outcome for several upper extremity surgeries performed for Galeazzi-type fractures, minimally displaced radial fractures, and carpal tunnel release [7-10]. The clinical relevance, therefore, of a motor-sparing neural blockade is that it can provide surgical anesthetic conditions while not interfering with immediate postoperative physical therapy.

In order to tailor a regional anesthetic to achieve the above goals, a rapid onset, short to medium duration local anesthetic is desirable. Mepivacaine is a cost-effective amide-type local anesthetic that works within this pharmacodynamic profile and may provide a reasonable anesthetic choice for this application. In light of these considerations, and the current tendency in clinical practice towards smaller LA volumes for US-guided neural blockade, we chose to use Mepivacaine 1.5% and reduce the LA dosage by reducing total injectate volume. Our study aimed to determine the incidence of motor sparing comparing the conventional LA dose of 30 mL and a reduced dose of 15 mL for upper extremity surgeries below the mid-humerus using a single-shot supraclavicular nerve block.

Methods

The study protocol was approved by the Institutional Review Board at the University of Miami, Miller School of Medicine, Miami, FL and all procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. A total of 43 patients, ASA class I to III, were screened for

participation in the study. All patients were scheduled to undergo orthopedic, oncologic, or incision and drainage surgery distal to the elbow under ultrasound-guided supraclavicular brachial plexus block. Written informed consent was obtained from all patients. Exclusion criteria included all contraindications to brachial plexus blockade, extremes of age (<18 or >90), preexisting neurologic disease or deficits in the operative limb, and localized infection at the injection site. Twenty patients were randomly assigned to each group according to a computer-generated randomization list. Group HIGH received the conventional injection dose of 30 mL of 1.5% Mepivacaine. Group LOW received the reduced volume dose of 15 mL of 1.5% Mepivacaine. No adjuvants were used.

The procedure was performed in an isolated preoperative block room. IV access was established and patients were placed on standard American Society of Anesthesia monitors and 2L supplemental oxygen via nasal cannula. Sedation was provided with intravenous titrations of midazolam 0-2 mg IV.

A ultrasound-guided supraclavicular nerve block was performed with an in-plane needle passage technique. Using a 12 MHz GE transducer (model 12L RS and GE Logic E ultrasound machine), the brachial plexus divisions were located in the sagittal plane, lateral to the subclavian artery. A 22 gauge insulated 50mm needle (Stimuplex A; B.Braun, Bethlehem, PA) was advanced in-plane at the lateral transducer edge towards midline, visualizing the tip at all times. A triple injection technique was employed, as previously described by Sainz Lopez et al. [5]. According to the study group, patients received either 5 mL or 10 mL boluses of 1.5% Mepivacaine at three designated sites, which included the interface between the subclavian artery and the first rib (i.e., "corner pocket"), the lateral border of the neural bundle, and the superior border of the bundle (Figure 1). All injections were made beneath the sheath of the brachial plexus, after confirming no aspiration of blood and no resistance to injection, in order to avoid either intravascular or intraneural infiltration. Care was taken to ensure that the injection was outside the plexus bundle, as evidenced by the absence of neural cluster "swelling". A blinded observer assessed all patients for degree of sensory and motor block in the distribution of the five terminal branches at 5, 10, 15, 20, and 30 minutes post-injection.

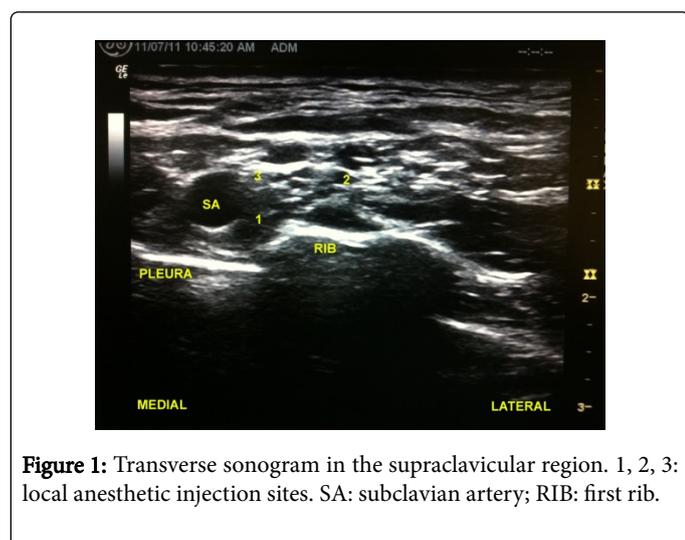


Figure 1: Transverse sonogram in the supraclavicular region. 1, 2, 3: local anesthetic injection sites. SA: subclavian artery; RIB: first rib.

Motor block was rated as complete (paralysis), partial (paresis), or none. Motor function was assessed in the following manner: wrist and

finger flexion (median nerve), wrist and finger extension (radial nerve), thumb adduction and flexor carpi ulnaris flexion (ulnar nerve), and biceps flexion (musculocutaneous nerve). Sensory block was assessed as complete/anesthesia (loss of sensation to pinprick), partial/analgesia (dull sensation to pinprick), or none (sharp sensation to pinprick). Sensory distribution was assessed in the following areas: thenar eminence and thumb tip (median nerve), dorsum of hand (radial nerve), fifth digit fingertip (ulnar nerve), and lateral aspect of forearm (musculocutaneous nerve). Successful blockade was defined, by convention, as complete sensory loss in the distribution of the radial, median, ulnar, and musculocutaneous nerves at 30 minutes of block performance. Failed blocks were managed with either LA supplementation at the corresponding spared nerve or conversion to general anesthesia (GA) intra-operatively, prior to incision. Necessary intraoperative local anesthetic supplementation injected by the surgeon was noted, and the block was also recorded as "failed". All patients received sedation with midazolam to a Ramsay Score of 3 (responding to commands) [11]. Any intraoperative conversion to GA due to surgical site pain was recorded and also considered a failed block. Patients were monitored for any signs/symptoms of drug toxicity immediately following the block and throughout the intraoperative and postoperative periods until discharge from the PACU. Telephone interviews were conducted on postop day 1 in order to assess the block duration. The incidence of postoperative block-related complications, such as prolonged blockade, new sensory or motor deficits, and paresthesias in the operative limb were also recorded.

Sample size and statistical analysis

Based on dose-finding studies by Tran et al., supraclavicular blocks require a minimum LA volume of 32 mL to achieve complete motor and sensory neural blockade in 90% of patients. In a study by Bertini et al., the local anesthetic volume, not the dose, was what affected motor block duration. In other studies, local anesthetic dose determined block intensity (sensory versus motor) and duration [12]. We hypothesized that reducing the MEV90 dose by a 50% decrease in LA volume should result in significant motor block sparing. Assuming a two-sided Type-1 error protection of 0.05 and a power of 0.95%, a total sample size of 40 patients was necessary to detect a 50% difference in motor-sparing incidence between the study and control groups.

Continuous variables are presented as mean + SD, and discrete or categorical variables as median and range or count and percentage. Tests of significance for continuous variables included the unpaired t-test or the Wilcoxon Ranked Sum for unpaired and non-parametric data (when appropriate); the Fisher's exact test was used for frequency count data.

Results

Of the 43 patients consented for the study, 3 were excluded due to screening failures. Forty patients qualified for statistical analysis. Twenty patients were assigned to each group. Patient samples were statistically similar (Table 1), although the HIGH group had fewer women. Four patients in each study group had failed blocks. In the HIGH group, 1 patient received intraoperative LA supplementation by the surgeon at the surgical site, and 3 patients received supplementary peripheral nerve blocks preoperatively. In the LOW group, 1 patient received intraoperative LA supplementation by the surgeon, 2 patients received supplementary peripheral nerve blocks, and 1 patient was converted to GA. Block success rate, defined as complete sensory block

(anesthesia) in the distribution of the median, radial, ulnar, and musculocutaneous nerves within 30 minutes of performing the SCB, was 80% in both groups (Figure 2). Complete motor block, defined as motor block (paralysis) in the radial, ulnar, musculocutaneous and median nerve distributions at 30 minutes, was present in 55% of patients in Group HIGH versus 10% in Group LOW and was statistically significant between both groups ($p < 0.01$) (Figure 3). The anatomic distribution of the observed motor-sparing was also statistically significant in the median ($p < 0.01$) and ulnar ($p < 0.05$) nerve branches among those patients who received 15 mL LA boluses (Figure 4). Complete sensory block onset was statistically faster at 20 minutes ($p < 0.05$) in the 30 mL group (Figure 5), but both groups demonstrated similar block onset by 30 minutes. Complete recovery from sensory and motor block, however, was not statistically different, despite a mean of 7.2 h + 3.4 vs. 5.7 h + 1.9 for the lower volume group.

Patient Characteristics	Group High	Group Low	
Age, years	42.3+17.8	49.1+15.7	P>0.05
Sex (male/female)	14/6	11/9	P<0.05
BMI, kg/m ²	28.3+6.3	25.7+3.8	P>0.05
ASA physical status (I/II/III)	9/10/01	5/13/02	
ASA: American Society of Anesthesiologists, BMI: Body Mass Index			

Table 1: Patient characteristics. Continuous variables as means ± standard deviation, 2-tailed t-test, categorical variables as counts, Fisher's exact test (2-tailed).

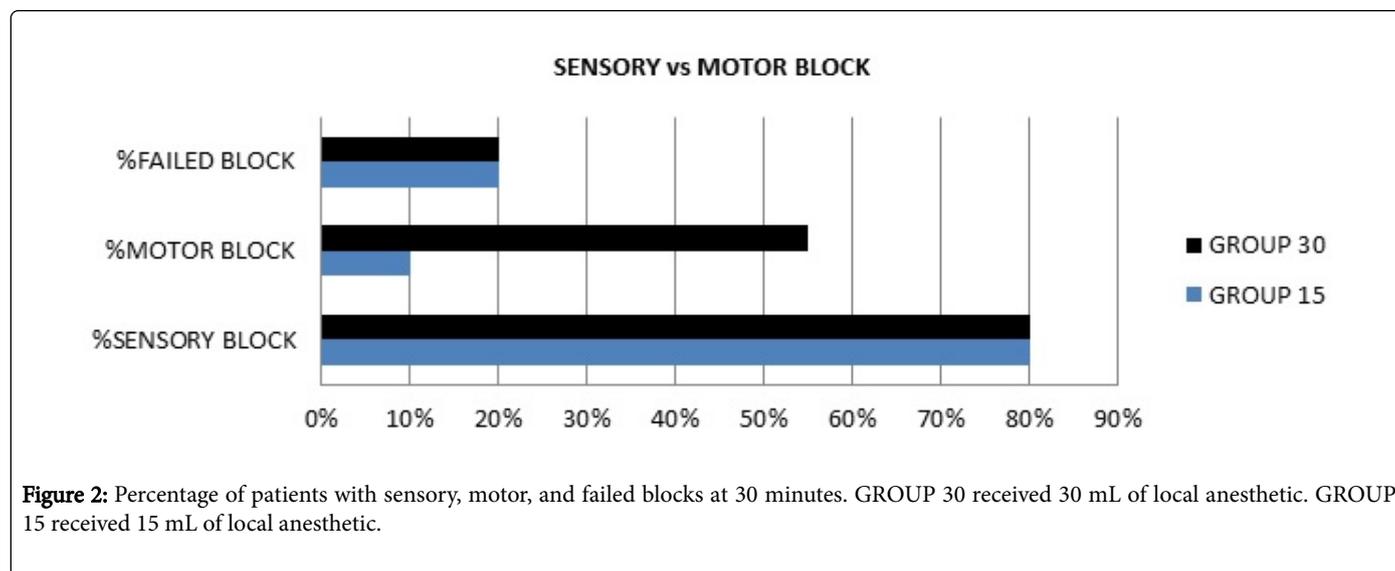


Figure 2: Percentage of patients with sensory, motor, and failed blocks at 30 minutes. GROUP 30 received 30 mL of local anesthetic. GROUP 15 received 15 mL of local anesthetic.

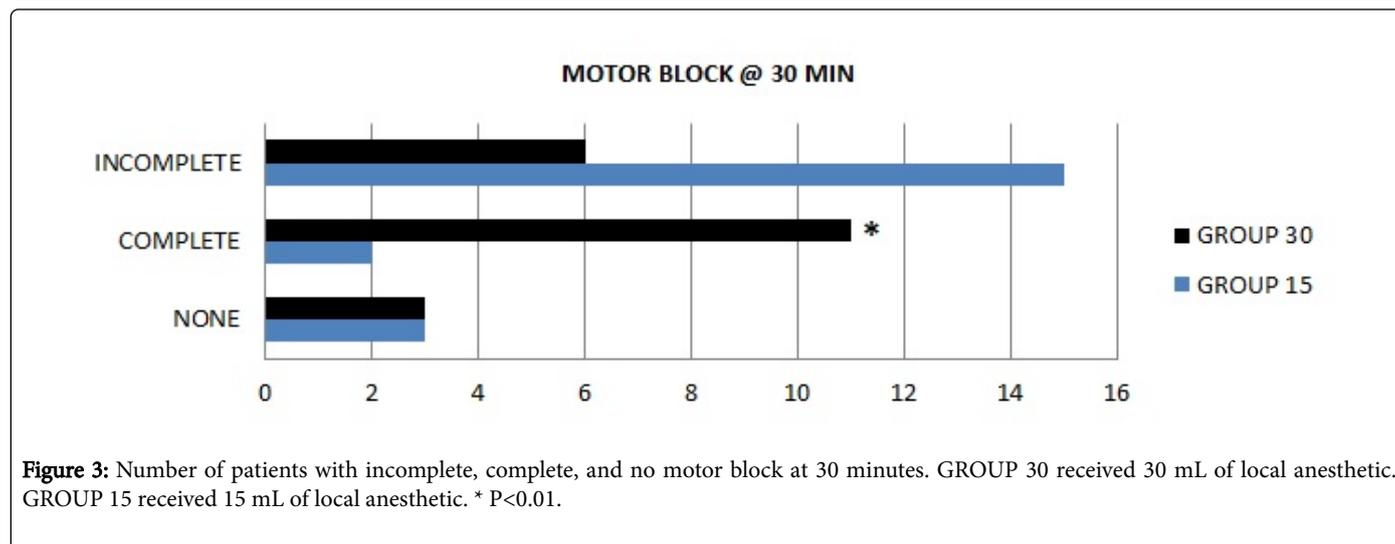


Figure 3: Number of patients with incomplete, complete, and no motor block at 30 minutes. GROUP 30 received 30 mL of local anesthetic. GROUP 15 received 15 mL of local anesthetic. * P<0.01.

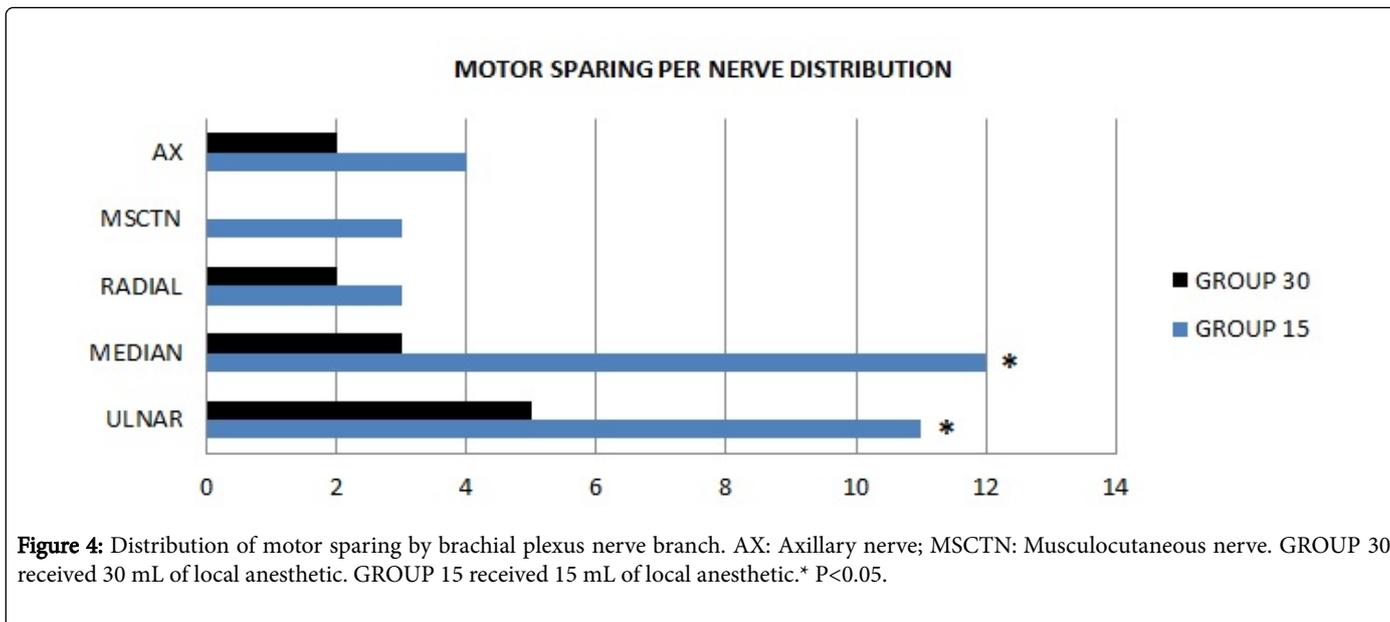


Figure 4: Distribution of motor sparing by brachial plexus nerve branch. AX: Axillary nerve; MSCTN: Musculocutaneous nerve. GROUP 30 received 30 mL of local anesthetic. GROUP 15 received 15 mL of local anesthetic.* P<0.05.

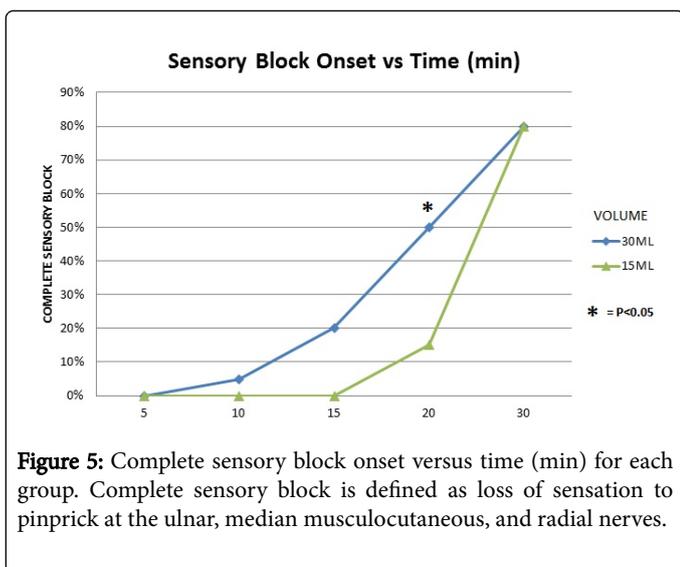


Figure 5: Complete sensory block onset versus time (min) for each group. Complete sensory block is defined as loss of sensation to pinprick at the ulnar, median musculocutaneous, and radial nerves.

There were no block-related adverse events. One patient was cancelled for surgery after block placement due to an intraoperative allergic reaction to an intravenous antibiotic infusion (diffuse urticarial rash and erythema). This patient was included in the study since the reaction occurred more than 45 minutes after block evaluation was completed and surgical stimulation testing. No neurologic complications were reported at the 24 hour telephone follow-up, and all patients confirmed complete recovery of motor and sensory function.

Discussion

The supraclavicular nerve block has often been nicknamed “the spinal of the arm” due to its rapid onset and dense anesthesia distal to the elbow. Several studies have already demonstrated that successful neural blockade may be defined in terms of complete sensory block [2,4,5]. The wide range of local anesthetic volumes reported to provide successful sensory blockade, and the current trends towards using

increasingly less injectate volumes prompted this investigation. Our data indicate no statistical difference in the incidence of complete sensory block following a volume of 15 mL of 1.5% mepivacaine versus a volume of 30 mL of the same local anesthetic solution. Motor sparing, however, is significantly greater ($p < 0.01$) in the reduced LA volume group, with an incidence of 90% sparing versus 45% in the conventional volume group. While our study was not designed to evaluate the effects of motor sparing on postoperative physical therapy or functional outcome, other research has demonstrated that limb paralysis negatively impacts early physical therapy [13]. This has been shown for ACL repair, total knee arthroplasty and hip arthroplasty [14,15]. Consequently, we believe that our results are of significant character in the context of a recent review by Ilfeld et al. that identified a lack of randomized control trials to document postoperative benefits for axillary and supraclavicular nerve block approaches [13]. Our data begins to address this evidence gap and suggests new areas of research to further understand the implications of these particular blocks on postoperative patient functional outcomes, and not just perioperative analgesia. Considering that the economic impact of carpal tunnel surgery exceeds \$2 billion per year in productivity and wage reimbursement costs, the socioeconomic impact of facilitating immediate physical therapy in this subset of upper extremity surgeries is enormous [16].

There are several possible explanations why lower LA volumes may provide adequate sensory blockade while sparing motor function. Differential sensory-motor blockade may explain the increased motor-sparing observed in the lower LA volume group [17,18]. Another consideration is the anatomical distribution of motor versus sensory fibers within the brachial plexus at the level of the divisions and its influence on the exposure of each nerve fiber type to the LA bolus [19,20]. This “somatotopic organization” of fiber type within the fascicles has been described in both humans and animals [20-23]. In fact, “the somatotopic organization of fiber types within fascicles, with both myelinated and unmyelinated fibers being segregated according to their function,” has been specifically supported by physiologic evidence in studies by Hallin and Roberts [21,22].

Although our study demonstrated positive results for the use of low volume injections, these findings may not be reproducible if alternative techniques or LA agents are selected. Our decision to use a triple-injection technique was based on the desire to maximize local anesthetic spread throughout the brachial plexus architecture when applying reduced volumes. It also provided a means of standardizing the location of the local anesthetic within the plexus sheath between study groups, since it is widely recognized that large, single bolus injections can result in unpredictable spread [24].

Another limitation of our study was related to the selection of local anesthetic agent. Mepivacaine is characterized by its rapid onset, and density of motor and sensory neural blockade [25-27]. While we selected this agent for those benefits, our selection raises the question whether the same results would be reproducible with long-acting agents like Ropivacaine that demonstrate greater sensory blockade than motor. While it may be argued that the 30 minutes of evaluation may have been insufficient to detect the onset of motor blockade in all patients, dose-finding studies for 1.5% Mepivacaine define the MEV90 at 20 minutes for both sensory and motor blockade [27]. It is unlikely, therefore, that differences in motor-sparing between the groups are attributable to delayed block onset.

Finally, the use of low volume injections for surgical anesthesia may not be appropriate for all nerve block approaches. Our choice of the supraclavicular approach was based on the relative compactness of the brachial plexus nerves (divisions) at this level. Such distinct neural architecture may facilitate block onset and density when compared to other approaches. It cannot be excluded, however, that the total neural surface area relative to the LA volume may have contributed to the different block characteristics we observed between the two groups. Such anatomic factors may present a significant obstacle to adequate local anesthetic spread and thereby decrease the success of low-volume injections in other less compact areas, such as the femoral or axillary approaches. Additional research would aid in determining the appropriate selection of nerve blocks for low-volume applications and further long-term patient benefits may be demonstrated by future research in these areas.

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