Concomitant infraclavicular plus distal median, radial, and ulnar nerve blockade accelerates upper extremity anaesthesia and improves block consistency compared with infraclavicular block alone

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Background. This prospective, randomized, observer-blinded study tested the hypothesis that a combined ultrasound-guided block of the infraclavicular brachial plexus plus distal median, radial, and ulnar nerves would accelerate upper extremity anaesthesia compared with infraclavicular block alone.

Methods. Elective wrist and hand surgery patients were randomly assigned to receive 42 ml infraclavicular lidocaine 1.5% with epinephrine 1/200 000 (‘infraclavicular only’; n = 30) or 30 ml lidocaine 1.5% with epinephrine 1/200 000 followed by a distal median, radial, and ulnar nerve block using 12 ml 50:50 lidocaine 2% + ropivacaine 0.75% (‘combined’; n = 31). A blinded observer assessed pinprick sensory and motor block in the four distal nerve territories at 10 and 15 min (each nerve/parameter: no block, 3, to complete block, 0).

Results. Total aggregate block score (sensory + motor) was reduced in the combined group at 15 min [mean (95% confidence interval) = 6.7 (5.3–8.1) vs 9.9 (7.9–11.9), mean difference (95% confidence interval) = 3.2 (0.81–5.6), P = 0.01], and corresponded to an estimated onset effect time benefit of 6 min (~40% treatment effect). The combined group also demonstrated reduced variance about the mean (SD = 3.7 vs 5.4, P = 0.046). Mean (SD) total block score (sensory + motor) was significantly reduced at 15 min in the combined group for each individual nerve [median, radial, ulnar, respectively: 1.4 (1.1) vs 2.4 (1.5), P = 0.005; 1.2 (1.1) vs 2.0 (1.5), P = 0.03; 1.6 (1.3) vs 2.5 (1.6), P = 0.03].

Conclusions. At an approximately equivalent total local anaesthetic dose, a combined infraclavicular block plus distal median, radial, and ulnar nerve blockade accelerates anaesthesia onset time and improves block consistency compared with an infraclavicular block alone.


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Compared with general anaesthesia, peripheral nerve block improves early outcome after wrist and hand surgery. These outcome benefits include improved analgesia, reduced nausea/vomiting, and reduced length of recovery room and hospital stay. However, onset time remains a barrier to the use of peripheral block for this surgery. Interventions aimed at reducing onset time have been investigated with varying results. An intervention not specifically investigated with respect to block onset is the concomitant administration of local anaesthetic at separate sites along the brachial plexus. This approach has become feasible and less invasive with the availability of ultrasonography. Ultrasound-guided infraclavicular block has been shown to be an effective and efficient technique for brachial plexus block, and in experienced hands, it can be performed in 2–3 min. The median, radial, and ulnar nerves also have distal positions at which each can be readily blocked.

The primary aim of this study was to test whether a combined block of the infraclavicular brachial plexus and distal median, radial, and ulnar nerves would accelerate upper extremity anaesthesia.
extremity anaesthesia compared with an infraclavicular block alone, when an approximately equivalent total local anaesthetic dose was used. Secondary studied endpoints included procedural pain and surgical anaesthesia success.

Methods

The New Zealand Northern Y Regional Ethics Committee approved the study, and the Australian and New Zealand Clinical Trials Registry provided prospective registration (ACTRN1261000155099, February 2010). We enrolled adult ASA I–III patients, aged 18–80, of all BMIs, undergoing elective wrist and hand surgery at the Southern Cross North Harbour Hospital and Northern Clinic from February to September 2010. Patients who refused brachial plexus block, had known neuropathy involving the arm undergoing surgery, or known amide local anaesthetic allergy were excluded. Written informed consent was obtained for all study procedures.

Infraclavicular only or combined group randomization was by computer-generated random number delivered in prepared sealed opaque envelopes. The randomization was done by a research assistant at a site remote from the study procedures (Fig. 1). An operator experienced in ultrasound-guided regional anaesthesia (M.J.F.) placed all blocks in a dedicated room. Immediately before block placement, midazolam 2 mg and alfentanil 0.5 mg were given i.v. All patients first received an infraclavicular brachial plexus block with an 18 G Tuohy needle (Portex, Kent), a high-resolution ultrasound machine (SonoSite M-Turbo, SonoSite, Bothell, WA, USA) and lidocaine 1.5% with epinephrine 1/200 000 (infraclavicular only=42 ml; combined=30 ml). Patients were supine with the arm to the side, the head turned slightly away, and a pillow placed between the shoulders to produce extension and therefore facilitate deltopectoral groove exposure. An 8–5 MHz curvilinear probe (SonoSite C11) was placed in the deltoplectoral groove in the sagittal plane with a medial-to-lateral position dictated by the best imaging of the axillary artery middle third. First, the skin, subcutaneous tissue and pectoralis muscles were infiltrated with local anaesthetic under ultrasound guidance. Subsequently, the 18 G Tuohy needle was advanced using in-plane needle-probe alignment, with the bevel facing dorsally to a position posterior to the axillary artery. This endpoint necessitates a distinct give as the septum posterolateral to the axillary artery is penetrated. At this point, full local anaesthetic deposition occurred regardless of brachial plexus cord visualization.

However, some needle manipulation in a cephalo-caudal direction was permitted to promote a ‘shallow saucer’ shaped or ‘bubble’ pattern spread dorsally to the artery (double bubble sign).

In the combined group, immediately after the infraclavicular injection, patients received an ultrasound-guided median, radial, and ulnar nerve block. All were performed with the same ultrasound machine but a 10–5 MHz linear array probe (SonoSite L38) and a 22 G 5 cm B-Plex™ needle (Plexufix, B)Braun, Bethlehem, PA, USA), an in-plane needle imaging technique and 12 ml (4 ml each nerve) of a 50:50 mixture of lidocaine 2%+ropivacaine 0.75%.

The procedural objective was to place local anaesthetic in proximity, in at least two positions (ideally each side) around the nerves but specifically avoiding intraneural injection as follows:

(i) Median nerve. Mid forearm between the flexor digitorum profundus and flexor digitorum superficialis muscles. The arm was abducted and externally rotated with the palm facing up. Needle advancement was in-plane from radial to ulnar.

(ii) Ulnar nerve. Approximately the junction of the middle and proximal third of the forearm, proximal to the divergence from the ulnar artery. The arm was abducted and externally rotated with the palm facing up. Needle advancement was in-plane anterior to posterior.

(iii) Radial nerve. Approximately the junction of the middle and distal thirds of the arm just distal to the nerve leaving the humeral spiral groove. The arm was adducted and internally rotated with the forearm resting on the chest. Needle advancement was in-plane anterior to posterior.

In the infraclavicular only group, no further regional procedure was performed before block testing. At 20 min, after block testing but before surgery, depending on the planned surgery and anticipated postoperative pain, patients received an additional median, radial, or ulnar nerve block as described above using 4–12 ml ropivacaine 0.375%.

In both groups, before block testing, the operative arm was wrapped with a crepe bandage from the mid arm to mid forearm to conceal the treatment group, thereby blinding the researchers testing block onset.

Most surgery was conducted awake, and a tourniquet was used in all patients. The primary surgeon (M.R.B., S.C.), who was blinded to treatment group, determined, in the case of inadequate surgical anaesthesia, the need for additional intraoperative local anaesthetic infiltration or deep sedation. Anxious patients received additional midazolam as required with the intention of remaining responsive to verbal commands throughout the procedure. Subjects refusing awake surgery were given an infusion of propofol (target concentration 2.0–3.0 μg ml⁻¹) with supplemental oxygen 1–4 litre min⁻¹ as necessary. Intraoperative and postoperative care was as previously described.

Data collection

Infraclavicular block procedural time was recorded by the principal investigator and defined as the time from the ultrasound probe being placed on the skin before needle puncture until the needle exited the skin after local anaesthetic administration. Subsequent distal block procedural time was not recorded. A blinded observer (F.S.H.T., Carlus Dovens and Tracey Tooley) assessed pinprick sensory and motor block at 10 and 15 min in the distribution of the median (tip of index, thumb abduction); radial (first dorsal webspace, wrist extension); ulnar (tip of little, finger abduction); and musculocutaneous nerves
(lateral distal forearm, elbow flexion/forearm supination) with time zero defined as the time the infraclavicular block needle exited the skin. Sensory block was graded on a four-point scale (same sharpness, 3; reduced sharpness, 2; sensation present but not sharp, 1; or absent, 0) relative to pinprick sensation in the contralateral arm. Motor block was also graded on a four-point scale (normal power, 3; reduced power, 2; flicker of movement only, 1; no movement, 0) relative to the contralateral arm. At the end of block testing, the patient was asked to rate discomfort during the block on a scale of zero to 10.

The principal investigator recorded the need for surgical wound infiltration and patient requested sedation or general anaesthesia. Surgical anaesthesia success was defined as surgery without the need for surgical site infiltration or deep sedation administered for intraoperative pain. Patients who received deep propofol sedation after declining awake surgery were not labelled as having failed surgical anaesthesia.

All data collection was observer blinded except data collected by the principal investigator. Placebo distal nerve
block injections were not used in the infraclavicular only group; therefore, patients were not blinded to the treatment group.

**Statistical analysis**

The data distribution was first evaluated using the D’Agostino and Pearson omnibus test. Categorical outcomes were compared using Fisher’s exact test (procedure-related paraesthesia). Ordinal outcomes (procedure-related pain scores) were compared using the Mann–Whitney U-test. Data fulfilling criteria for a Gaussian distribution were compared using the unpaired t-test (all aggregate block scores). The 15 min aggregate block score variances were compared using the F-test. A P-value of < 0.05 was considered significant.

Other data are summarized using appropriate descriptive statistics [mean (sd) or mean (95% confidence interval) for normally distributed or symmetric variables; median and inter-quartile ranges for skewed variables; number and proportion for categorical variables]. Statistical analysis was performed using Prism 5.0c (Graphpad Software Inc., La Jolla, CA, USA).

Sample size calculations were based on total aggregate block score at 15 min. We considered a 7 min change in onset time as clinically relevant at 15 min. A previous study involving a similar infraclavicular block in a similar group of patients demonstrated a 10 and 20 min mean (sd) total aggregate block score of 11 (5.2) and 5.7 (4.9), respectively. Assuming an approximately similar linear reduction in total aggregate score, a 7 min shift in onset time would correspond to an estimated onset time benefit of 6 min (0.7 × (11 – 5.7)). We calculated that 60 patients would be required to detect this mean total aggregate block score shift with 80% power (two-sided unpaired t-test, 5% significance level; StatMate 2, Graphpad Software Inc.). Primary outcome post hoc power analysis revealed that the study had 87% power to detect a mean shift in total aggregate block score of 3.7 at the 5% significance level (Statmate 2).

**Results**

A total of 62 patients were recruited: 30 patients were randomized to the ‘infraclavicular only’ group and 32 patients to the ‘combined’ group (Fig. 1). One combined group patient was excluded after randomization due to a protocol violation when 2% lidocaine with epinephrine was used for the infraclavicular block. The patient had a 15 min aggregate block score of 4, and no intraoperative supplementation was required. No significant differences were found in patient and surgical characteristics between the groups (Table 1).

Procedure-related numerical rated pain was similar between the groups (Table 2). At 15 but not 10 min, total aggregate block score (sensory + motor) was reduced in the combined group [mean (95% confidence interval) = 6.7 (5.3 – 8.1) vs 9.9 (7.9 – 11.9), mean difference (95% confidence interval) = 3.2 (0.81 – 5.6), P = 0.01] (Table 3, Fig. 2) and corresponded to an estimated onset time benefit of ~6 min (~40% treatment effect). At 15 min, the combined group also demonstrated reduced variance about the mean (s0 = 3.7 vs 5.4, P = 0.046) (Fig. 2).

Conscious sedation was requested in seven and four patients in the infraclavicular only and combined groups, respectively, while deep sedation was requested in six and five patients, respectively. Intraoperative pain was reported in two (6.7%) and three (9.7%) patients in the infraclavicular only and combined groups, respectively. Management included intraoperative local anaesthetic infiltration (infraclavicular only, 1; combined, 1) and deep sedation (infraclavicular only, 1; combined, 2). No patient demonstrated symptoms or signs of systemic local anaesthetic toxicity.

### Table 1 Patient and surgical characteristics. Values are mean (sd) or n. f, female; M, male

| Block placement details. Values are median (IQR) or n. NRPS, numerical rating pain score (0 no pain, 10 worst pain imaginable) |
|--------------------|------------------|------------------|------------------|
|                     | Infraclavicular only (n = 30) | Combined (n = 31) | P-value |
| Infraclavicular procedural time (s) | 90 (60–120) | 90 (51–127) | 0.11 |
| Procedure-related NRPS | 1 (0–2) | 2 (1–3) | |
| Procedure-related paraesthesia | 1 | 5 | 0.21 |
| Distal peripheral nerve block: | | | |
| Median | 26 | 31 | |
| Ulnar | 13 | 31 | |
| Radial | 19 | 31 | |
**Discussion**

To our knowledge, this is the first study to investigate the effect of a concomitant proximal and distal brachial plexus block at an approximately equivalent local anaesthetic dose. Infraclavicular block combined with distal median, radial, and ulnar nerve blocks was associated with accelerated upper extremity anaesthesia and improved block consistency compared with an infraclavicular block alone.

An evolving approach to anaesthesia/analgesia for wrist and hand surgery is to administer a short-acting brachial plexus block and long-acting distal blocks. This facilitates the goals of tourniquet analgesia, surgical anaesthesia, and prolonged postoperative analgesia, while also accelerating the early return of upper arm motor function. Our previous clinical experience, supported by continuous interscalene analgesia studies, is that many patients experience dissatisfaction from the prolonged arm weakness associated with ropivacaine brachial plexus block. Reduction in proximal arm motor block prompted our initial interest in the technique. The hypothesis of accelerated anaesthesia was raised after having used the technique for some time.

With regard to our findings of accelerated onset and improved block consistency, the distal nerves are more...
superficial than the plexus cords, and consequently, are more readily sonographically imaged. Local anaesthetic may have thus been delivered more intimately to the peripheral nerves compared with the cords. The ratio of neural to non-neural tissue is different along the brachial plexus and may influence individual nerve fibre permeability to local anaesthetic.\textsuperscript{14} Another possible mechanism is involvement of a threshold number of nodes of Ranvier for conduction block. More likely, however, was the greater surface area of neural tissue available to local anaesthetic in the combined group compared with the infracavicular only group. The reduced variance about the mean demonstrated in the combined group likely reflected the ease of local anaesthetic placement in proximity to the distal nerves.

The routine performance of two separate procedures for surgery traditionally requiring only one regional block procedure might seem invasive. Distal blocks in particular have often only been indicated to supplement an inadequate brachial plexus block or to provide the primary anaesthesia for hand surgery.\textsuperscript{15,16} However, ultrasound guidance lessens the invasiveness of both procedures—in particular, the distal blocks. These nerves are readily visualized at the sites described, and arguably, are minimally invasive procedures. The choice of distal block local anaesthetic and concentration reflects our routine practice of distal perineural ropivacaine for postoperative analgesia and lidocaine alone for infracavicular block. However, the onset time of an equipotent concentration of ropivacaine is slower than lidocaine.\textsuperscript{17}

Furthermore, the distal blocks were administered after the infracavicular block and the local anaesthetic in the combined group was effectively being given later than in the infracavicular only group. Therefore, it was thought that to offset the effect of ropivacaine and delayed local anaesthetic administration on onset time in the combined group, a higher local anaesthetic concentration would be required in this group: ropivacaine 0.75% is approximately equipotent to lidocaine 2%,\textsuperscript{17,19,20} which equates to an ~25% higher effective concentration for the distal blocks than the infracavicular block.

We summed the ordinal sensory and motor scores to produce an aggregate value with an approximately Gaussian distribution, thus enabling a between-group comparison using a t-test. This was justified on the basis of sensory and motor block having equal clinical importance, and being graded on the same ordinal scales. Alternative statistical approaches, with fewer required assumptions, include individual sensory and motor score analysis using a non-parametric test; or by analysing block progression as categorical data over time (e.g. with the Kaplan–Meier curves), using the log-rank test.

For clinical investigations, it is preferable to use a clinical outcome (e.g. surgical anaesthesia) over a surrogate outcome (e.g. block score) as the primary endpoint. The use of the aggregate block score as the primary endpoint, therefore, represents a potential limitation. However, this limitation is mainly an issue for non-randomized trials lacking a control group. Furthermore, block progression scoring is useful in estimating differences in block onset, and data from a previous study enabled an approximation of the likely onset time benefit (~6 min) from the observed total aggregate block score treatment effect (mean group difference = 3.2).\textsuperscript{3} In addition, outcomes such as aggregate block score can detect clinically relevant effects without having a significant number of patients fulfil criteria for block failure.

The clinical relevance of a 6 min benefit in onset time may also be questioned. However, a 6 min effect at 15 min represents a 40% treatment effect and may be clinically relevant to anaesthetists whose practice necessitates establishing surgical anaesthesia during patient turnaround time.

Other limitations include caution in interpreting the surgical success rates between groups in the light of the infracavicular only group receiving supplementary distal blocks at the discretion of the operating investigator. Full double blinding was not possible because sham distal blocks were not used, and generalizability is always a potential issue with single operator-based technique studies.

In summary, this study shows that an infracavicular block combined with blocks of the distal median, radial, and ulnar nerves is associated with accelerated block onset and improved block consistency compared with an infracavicular block alone. These results will be particularly relevant in clinical settings where upper extremity anaesthesia onset time has logistic importance.

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**Conflict of interest**

None declared.

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