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ARTICLE

Comparison of the effectiveness of local anesthesia for the digital block between single-volar subcutaneous and double-dorsal finger injections: a systematic review and meta-analysis of randomized control trials

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ABSTRACT

Local anesthesia is an effective method to perform digital nerve blocks. In this study, we compare the effectiveness of single-volar subcutaneous and double-dorsal injection through a systematic review and meta-analysis of randomized controlled trials (RCTs). A systematic search of PubMed, Embase, and the Cochrane Library from inception to 7 April 2021 was performed. RCTs with the effects of single-volar subcutaneous and double-dorsal injection were eligible. Meta-analysis was performed using random effect models with pooled standardized mean differences (SMDs) and 95% confidence intervals (CI). RoB 2.0 and GRADE of Recommendation Assessment, Development, and Evaluation criteria were applied for evaluating the bias. A total of 2484 studies were initially identified, with 11 eligible RCTs finally included in the meta-analysis (1363 patients). The pooled data of nine studies showed single-volar injection had a statistically significantly lower pain score (pooled SMD: 0.20, 95% CI, 0.01 to 0.39, $p = 0.041$, $I2 = 58\%$, $N = 1187$) and higher patient preference but invalid anesthesia at the dorsal proximal digit. No significant differences were observed in the onset of anesthesia, adjacent digit invalid numbness, distal phalanx invalid anesthesia, additional injection rate, and adverse effects. In conclusion, this meta-analysis of RCTs showed that the single-volar injection was associated with a lower pain sensation during injection and higher patient satisfaction with a reduced anesthetic effect over the proximal dorsal phalanx. Further high-quality RCTs with a higher number of cases are needed to validate our results.

Abbreviations: RCT: randomized controlled trials; SMD: standardized mean differences; CI: confidence intervals; WALANT: wide-awake local anesthesia no tourniquet; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RR: risk ratio; IENFD: intraepidermal nerve fiber density

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Digital block; local anesthesia; volar injection; dorsal injection; systematic review; meta-analysis; randomized control trial

Introduction

In finger surgery, digital nerve blockade is frequently used as an effective and safe technique to numb the fingers. For certain types of hand operations, such as tendon repair, tenolysis, and scar contracture release surgery, local anesthesia allows surgeons to assess the active range of motion intraoperatively to confirm that the tendon repair is solid and that there is no gap between tendon stumps [1–4].

There were many ways to perform digital nerve blockade, including transmetacarpal block with two dorsal punctures, dorsal digital block, transthecal volar block, volar subcutaneous block, circumferential subcutaneous ring block [5–14]. Lalonde also proposed the concept of wide-awake local anesthesia no tourniquet (WALANT) surgery, enabling surgeons to perform hand surgeries more easily [2,3,15–22]. As the use of these new techniques has expanded, so has the use of local anesthesia for finger operations.

From the literature review, the most commonly used digital nerve blockades are double dorsal injection, single volar subcutaneous injection, and transthecal injection. A previous meta-analysis of these methods found that single volar subcutaneous injections and double-dorsal injections were similar in injection pain and produced less pain than transthecal injections [23]. We, therefore, focus on the two better techniques. Our study aimed to perform a meta-analysis of randomized controlled trials (RCTs) to compare the effectiveness of single-volar subcutaneous and double-dorsal injections for digital anesthesia in a broader range of discussion in this essential field of local anesthesia for finger surgery.

Material and methods

This systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses

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(PRISMA) guidelines and has been registered with PROSPERO (CRD42021226004) [24].

Search strategy

A literature search of PubMed, Cochrane Collaboration Central Register of Controlled Clinical Trials, Cochrane Systematic Reviews, and Embase was performed from the date of inception until 7 April 2021. We also manually searched the reference lists of the included studies. The search terms of each database are detailed in Appendix.

Screening and inclusion criteria

Three reviewers (CHL, MHL, and RWH) independently identified eligible studies. The titles and abstracts of all studies were carefully screened if they met our inclusion criteria. There were no restrictions on age or language. Only RCTs relevant to volar or dorsal local injections for the digital block were retrieved. Transthecal injections, prospective nonrandomized studies, review articles, retrospective studies, case series, case reports, commentaries, conference abstracts, and trail registrations were excluded. All retrieved studies were required to report at least two local injection methods including double-dorsal or single-volar subcutaneous injections for digital nerve block. The target population comprised patients who received digital local anesthesia, either performed as a single volunteer or surgical procedure for finger injuries. When encountering duplicate publications or patient groups, only the most recent study with more complete patient data was included.

Data extraction and quality assessment

After reviewing the full texts of the identified studies, three independent authors (CHL, MHL, and RWH) performed data extraction and cross-checked the eligible studies. Discrepancies in article selection and data extraction were resolved by the discussion of all three reviewers. The extracted variables included authors' names, year of publication, study design, patients' demographics (age, gender) mean follow-up period, injection medication, needle size, etiology and location of local anesthesia, outcome parameters (injection pain score, onset of anesthesia, duration of anesthesia, anesthetic failure rate and complications). We requested any missing data from the corresponding authors by email. The quality of the included studies was assessed using version 2 of the Cochrane risk-of-bias tool (RoB 2.0) [25]. Publication bias was assessed using funnel plots.

Statistical analysis

Outcome measurements including injection pain score, the onset of anesthesia, adjacent digit invalid numbness, dorsal proximal digit invalid anesthesia, distal phalanx invalid anesthesia, additional injection rate, patient preference, and adverse effects were extracted to evaluate discomfort during injections at different locations. Studies that reported means and standard deviations of the outcome measurements were included for further meta-analysis. Meta-analysis was performed using random effect models with pooled standardized mean differences (SMDs) and 95% confidence intervals (CI). Review Manager (RevMan, Version 5.3, Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014) and RStudio (RStudio Team (2020), RStudio: Integrated Development for R. RStudio, PBC, Boston, MA, USA) were used for statistical analysis, and p-values < 0.05 were regarded to be statistically significant. The I^2 test was used to determine between-trial heterogeneity. Random effects models were used to calculate pooled estimates of mean differences to take potential inter-study heterogeneity into consideration.

Overall evidence assessment

GRADE (Grades of Recommendation Assessment, Development and Evaluation) criteria were applied by two independent reviewers (CH LEE and RW Huang) to summarize the quality of evidence for single-volar subcutaneous and double-dorsal injections. All data were considered to be high-quality evidence initially, however, this could be lowered according to the risk of bias, imprecision, inconsistency, indirectness, or publication bias [26].

Results

Literature search and selection

A total of 2474 records were retrieved (1611 from PubMed, 1703 from Embase, and 199 from the Cochrane Library), and 13 additional records were identified through other sources. A total of 2382 studies were excluded due to duplication, irrelevant titles, and contents. The full texts of the remaining 92 studies were assessed for eligibility, of which 11 were included for meta-analysis [23,27–35]. Figure 1 shows the PRISMA diagram of the selection process. The outcomes and the characteristics of the eligible articles are shown in Table 1.

Study characteristics

The 11 eligible studies were published from 2006 through 2021 and included a total of 1363 patients (Table 1) who received local anesthesia with either a single-volar subcutaneous ($N = 687$) or double-dorsal ($N = 676$) injection for digital anesthesia. The main indications for injections were repair or surgery for injured fingers, except for two studies that compared injections in the same individual [27,28]. The reported drop-out rate ranged from 0% to 30%.

Injection methods

Volar approach

The volar injection approach mostly followed Harbison's protocol. Local anesthetic was injected into the palmar subcutaneous tissue above the flexor tendon sheath at the level of the A1 pulley or palmar crease [12]. Lidocaine (1–2%), Mepivacain® (1%), or bupivacaine (0.5%) were injected using a 23–30-G needle. The injection was performed subcutaneously just deep to the skin at 2–4 mm depth with 1.8–3 mL per injection.

Dorsal approach

The traditional double-dorsal approach mostly followed Harris and Braun's protocol, first reported in 1924 [14]. Local anesthesia was injected into the base of the dorsal proximal phalanx, with two injections on each side of the finger 1 cm proximal to the metacarpophalangeal joint with the tip of the needle aimed toward the palmar skin at the level of the A1 pulley. A comparison of the two approaches is shown in Figure 2.

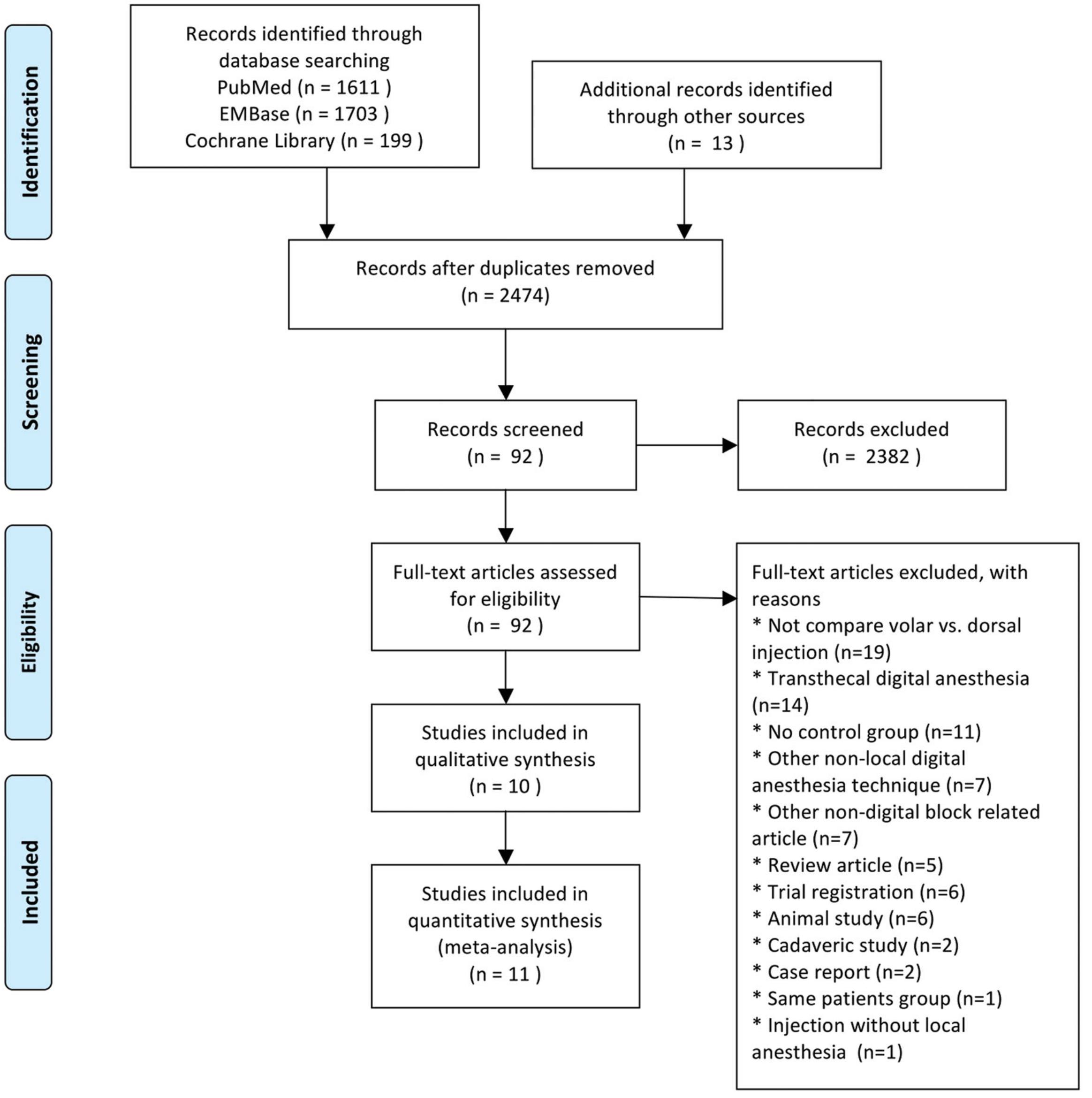


Figure 1. PRISMA diagram. The flowchart of the literature search and the process of study selection according to the PRISMA guidelines. *N* indicates number of studies.

Outcomes

Pooled mean injection pain score

Pooled data of nine studies showed a tendency of a lower pain score with a single-volar injection though with statistical significance and moderate heterogeneity across studies under a random-effects model (SMD: 0.20; 95% CI 0.01–0.39; $p = 0.041$; heterogeneity, $I^2 = 58\%$) (Figure 3(A)).

Pooled time to onset of anesthesia

Pooled data of four studies showed no significant difference in the onset of anesthesia (three studies used 2% lidocaine and one used 1% lidocaine) between double-dorsal and single-volar injections with high heterogeneity across studies under random-effects model (difference in meantime of onset [intervention – control] was 31.58 s; 95% CI −16.51–79.68; $p = 0.198$; heterogeneity, $I^2 = 99\%$) (Figure 3(B)).

Pooled adjacent digit invalid numbness

Pooled data of two studies showed no significant difference in the risk ratio (RR) of adjacent digit invalid numbness with a single-volar injection compared to a double-dorsal injection with high heterogeneity across studies under a random effects model (RR: 0.25; 95% CI 0.02–3.18; $p = 0.283$; heterogeneity, $I^2 = 94\%$) (Figure 3(C)).

Pooled dorsal proximal digit invalid anesthesia

Pooled data of three studies showed a significantly higher RR of invalid anesthesia in the dorsal proximal digit with a single-volar injection compared to a double-dorsal injection with moderate heterogeneity across studies under a random-effects model (RR: 0.18; 95% CI 0.06–0.53; $p = 0.002$; heterogeneity, $I^2 = 64\%$) (Figure 3(D)).

Pooled distal phalanx invalid anesthesia with subgroup analysis

Pooled data of seven studies showed an overall higher RR in distal phalanx invalid anesthesia at a combined time point with a single-volar injection compared to a double-dorsal injection with low heterogeneity across studies under a random-effects model (RR: 1.46; 95% CI 1.09–1.96; $p = 0.012$; heterogeneity, $I^2 = 0\%$). In subgroup analysis on 5 min after injection, four pooled studies showed a significantly higher RR in distal phalanx invalid

Table 1. PRISMA diagram of the selection process.

Study ID	Indication for anesthesia and exclusion criteria in each study	Dropout rate	Medication used for injection / Needle size	Method of Single-Volar Subcutaneous Injection	*N*	Method of Double-Dorsal Finger Injection	*N*	Sensation detection level / Type of detection / Time of evaluation	Outcome Parameters
Hung, 2005	**Indication:** healthy volunteers between 18 to 80 years old. **Exclusion:** pregnancy, history of adverse reaction to lidocaine, neurologic disease, peripheral vascular disease or inability to understand the directions. **Special note:** Each patient received all three types of injection in different time sequences. The thumb and small finger were not injected. Also included transthecal injection.	1/50 (2%, one patient was excluded due to missing data)	2 ml of 2% lidocaine at room temperature in a 3 ml syringe with a 25-G needle	Single injection into the palmar skin at the level of the A1 pulley.	49	Two Injections into the dorsal web space with the tip of the needle aimed toward the palmar skin at the level of the A1 pulley.	49	The palmar pulp and dorsal nail fold / light touch and sharp discrimination / 15 s intervals until distal sensation was abolished	1. Pain level during injection (Scale from 1 to 10) 2. Time to onset (Time to complete abolition of sensation) 3. Preference (patients ranked the blocks in order of preference) 4. Adverse effects (One week later, surveyed by telephone)
Williams, 2006	**Indication:** volunteers. **Exclusion:** a history of allergy to the agents, preexisting vascular insufficiency in the fingers such as might occur with Raynaud's disease or phenomenon, severe peripheral vascular disease, or a history of previous digital replantation or other vasospastic conditions. **Special note:** Each patient received both types of injection in different time sequences.	0%	1.8-ml cartridges of 2% lidocaine with 1:100,000 epinephrine with reusable dental syringe with a 30-G needle	Single 1.8-ml injection subcutaneously deep to the skin in the midline at the level of the proximal flexion crease of the long finger.	27	Two injections with 0.9 ml of anesthetic into the web spaces on either side of the long finger from a dorsal approach. Inserted 3 to 4 mm, directed toward the base of the digit.	27	Distal to proximal phalanx crease / pinprick testing / 30 min after the injections	1. Pain level VAS during injection (from 0-10) 2. Preference 3. Failure of anesthesia 4. Area of anesthesia 5. Duration of anesthesia 6. Adverse effects
Yin, 2006	**Indication:** patients between 14 and 60 years of age suffering injuries to one or two fingers distal to the basal crease of the finger who could be treated surgically under digital block. **Exclusion:** thumbs involved or their surgery would extend proximally into the palm.	2/91 (2.2%)	1% lidocaine in 5-ml syringe with a 27-G needle	Single 2-ml subcutaneous palmar injection block at the base of the finger.	41	Two injections on the dorsum of one side at the base of the proximal phalanx and directed around the bone toward the palmar skin. Total 3 ml	50	Distal to the DIP crease / pinprick sensation / after 5 min following injection, the digital block was regarded as a failure	1. Pain level VAS during injection (from 0-10) 2. Failure of anesthesia 3. Time to onset
Bashir, 2008	**Indication:** sixty fingers of 30 patients (two fingers of each patient) requiring surgical procedure distal to proximal phalanx crease. **Exclusion:** history of allergy to the agents, previous vascular insufficiency such as with Raynaud's disease or phenomenon, severe peripheral vascular disease, peripheral neuropathy or previous digital replantation.	0%	2 ml of 2% lignocaine with 1:100000 epinephrine with a 27-G needle	Subcutaneously injecting 2 ml of anesthetic in the midline, just short of the proximal flexion crease of the finger.	30	One ml of anesthetic was injected into the web space on either side of the finger from the dorsal side	30	Not reported / pinprick test / 5 min	1. Absence of pain during surgery 2. Number of adjacent numb fingers 3. Mean duration of anesthesia 4. Mean pain score
Cannon, 2010	**Indication:** patients > 16 years attending the Emergency Department with fingertip injuries/ infections (distal to the DIPJ)	5/76 (6.5% due to missing data)	2-3 ml of warmed 0.5% bupivacaine with a 25-G needle and covered all	Single injection of 2-3 ml of warmed 0.5% bupivacaine into the soft tissues close to proximal skin crease of	39	Two separate injections of local anesthetic (LA) around the four digital	37	Fingertip / pinprick test with 25-g needle / at 5 mins and 10 mins	1. Pain level during injection (Patient observational distress scores: 1-10) 2. Failure of anesthesia (5

(*continued*)

Table 1. Continued.

Study ID	Indication for anesthesia and exclusion criteria in each study	Dropout rate	Medication used for injection / Needle size	Method of Single-Volar Subcutaneous Injection	*N*	Method of Double-Dorsal Finger Injection	*N*	Sensation detection level / Type of detection / Time of evaluation	Outcome Parameters
	requiring digital local anesthesia. **Exclusion:** signs of digital nerve injury proximal to DIPJ, presence of another painful distracting injury, multiple finger injuries requiring blocks, psychotic mental illness, under the influence of drugs/alcohol, unable to consent, peripheral neuropathy, vasculopathy, English not primary language, injuries to the dorsum of digit proximal to PIPJ.		potential injection site(s) with gauze	MCPJ on the volar aspect of the injured finger.		nerves at the base of the finger			mins and 10 mins if still painful) 3. Clinician preference 4. Adverse effects
Kasmaei, 2013	**Indication:** finger-damaged and above 18 years of age. **Exclusion:** history of allergy to the local anesthetic drugs, evidence of an active local infection in the injection area, age below 18 years old, suffering from detected coalescence disorder, preexisting vascular insufficiency, severe peripheral vascular disease, history of previous digital replantation, previous participation of the subject in this study and presence of the lesion in the dorsal proximal phalanx.	0%	2% lidocaine, 1.8 and 3-4 ml were used in single-injection subcutaneous block and two-injection dorsal block groups, respectively	Single injection with the needle inserted 3 to 4 mm, directed toward the base of the digit subcutaneously just deep to the skin in the midline at the level of the proximal flexion crease of the damaged finger.	64	No details reported	64	Not reported / pinprick test / not reported	1. Pain level during injection VAS (from 0-10) 2. Time of effect onset 3. Preference (both physician and patient)
Afridi, 2014	**Indication:** patients above 16 years of age of either gender with pathology distal to first palmar digital crease such as trauma, tumor/lump, contracture, phalangeal fracture etc. **Exclusion:** patients with history of peripheral neurovascular diseases such as diabetes mellitus, Raynaud's disease or previous nerve injury, prior intake of any analgesic.	0%	3 ml lidocaine with adrenaline having the same concentration of 2%, in a 5-ml syringe and a 25-G needle	MCPJ flexed to 45 degrees to relax palmer skin. The needle was introduced at the centre of the proximal palmar digital crease and 3 ml of 2% lidocaine was injected subcutaneously, 2–3 mm deep to the skin.	63	Double injections with needles inserted through the dorsum sides at the base of proximal phalanx and directed around the bone towards the palmer skin. One ml of 2% lidocaine was injected to block the digital nerve, then the needle was slowly withdrawn and an additional 0.5 ml injected to block the nerve branches on the dorsum of the digit.	63	Check radial, ulnar, palmer and dorsal aspects of the involved digit / pinprick with an 18 gauge / 15 s interval until distal sensations were abolished.	1. Pain level during injection VAS (from 0-10) (not reported) 2. Time to onset 3. Duration of anesthesia 4. Failure rate (If there was no loss of sensation after 15 min, the block was considered failed)
Martin, 2016	**Indication:** over 18 years old and presented to the Emergency Department with a finger injury that required digital anesthesia for assessment or treatment. **Exclusion:** digital nerve injury proximal to the distal interphalangeal joint; a tendon sheath infection; peripheral neuropathy, vasculopathy or skin	18/86(30%) lost to follow-up after 7 days of intervention	1% lidocaine	Two to three ml of lidocaine 1% was injected in the SC tissue just distal to the MCPJ flexion crease of the palm.	46	One ml of lidocaine was injected into each side of the proximal phalanx just distal to the MCPJ	40	Not reported / not reported / 5 min after the injection	1. Pain level VAS (100 mm) in the beginning and 5 min after injection 2. Failure of anesthesia (ability to assess and treat the injured finger without supplementation to the initial digital nerve block) 3. Adverse effect

(*continued*)

Table 1. Continued.

Study ID	Indication for anesthesia and exclusion criteria in each study	Dropout rate	Medication used for injection / Needle size	Method of Single-Volar Subcutaneous Injection	*N*	Method of Double-Dorsal Finger Injection	*N*	Sensation detection level / Type of detection / Time of evaluation	Outcome Parameters
	diseases involving the finger; or were unable to consent.								
Schelhorn, 2016	**Indication:** isolated injury to a finger, which could be treated with finger local anesthesia. **Exclusion:** thumb injury, progressive infection with visible redness at the injection point. not proficient in the German language and patients with mental deficits	0%	3 ml of Mepivacaine® 1% with hypodermic needle (0.55 × 25 mm BD Microlance TM3) (equal to 24 G)	Single subcutaneous digital block by injecting local anesthesia in the middle of palmar MCPJ flexion crease of the left middle finger.	96	Place one group of conduction anesthesia by injecting local anesthesia into the radial and ulnar sides at the base of the finger on the extensor side near the neurovascular bundle	94	Not reported / not reported / 5 min after the injection	1. Pain level in the beginning (VAS from 0-10) and 5 min after injection (painless, sufficient painless, insufficient painless (require re-injection)) 2. Failure of anesthesia (re-injection) 3. Adverse effect\s
Okur, 2016	**Indication:** patients ≥ 18 years of age with digital lacerations requiring suturing with digital nerve block; presentation to hospital within 6 h after the laceration after patient approval. **Exclusion:** patients with artery, tendon, or nerve injury and finger fractures; patients had pathologies which could lead to finger ischemia such as peripheral vascular disease, diabetes mellitus, Raynaud's phenomenon, Buerger's disease, burns, and crush injuries.	0%	lidocaine hydrochloride 20 mg (2%) and epinephrine 0.0125 mg per milliliter, 5-ml injectors, and a 26-G needle	The needle was introduced vertically through the distal joint line of the palmar side of the MCPJ, and 3 ml of lidocaine was injected completely.	25	1.5 ml of lidocaine hydrochloride was injected into the medial side of the extensor hood at the level of the proximal finger crease. After having injected half of the ingredient superficially in the first entry, the needle was slowly pushed forward to the volar side and the other half was given. The same procedure was repeated on the lateral side of the finger and a total of 3 ml was administered for anesthesia.	25	Finger pulp / pinprick sensation / not mentioned	1. Pain level VAS (from 0-10) and suturing pain score 2. Time to onset 3. Failure of anesthesia (enable suturing within 10 min of injection) 4. Adverse effect
Clement, 2021	**Indication:** aged 18 years or older presenting with an injury of the finger requiring regional anesthesia for surgical treatment without prior systemic analgesia. **Exclusion:** patients presenting with injury on the dorsal side of the proximal phalanx of the finger, if adjacent fingers in one hand were injured, in the presence of distracting injury, pre-existent sensory disorder or dystrophy of the hand, if the injury could not be treated in the Emergency Department or if the patient was unable to consent (because of language barrier, intoxication or other mental disorder).	0%	3 ml of lidocaine 1% at the base of the injured finger or thumb with 23-G syringe	The syringe punctured the skin with a 45-degree angle at the palmar side and the fluid was injected in the subcutaneous space.	209	Dorsal block anesthesia was performed by injecting 3 ml lidocaine 1% at both lateral sides just distal to the MCPJ of the proximal phalanx at the level of the webspace of the injured finger or thumb.	200	Six different regions of the finger / tweezers / 5 and 10 min after injection	1. Pain level NRS-score (from 0-10) during injection 2. Extent of anesthesia 3. Failure of anesthesia (second injection) 4. Preference (clinicians' satisfaction) 5. Adverse effects

N: number of fingers; VAS: visual analog scale; DIP: distal interphalangeal; DIPJ: distal interphalangeal joint; PIPJ: proximal-interphalangeal joint; MCPJ: metacarpophalangeal joint; SC: subcutaneous; NRS: numerical rating scale.

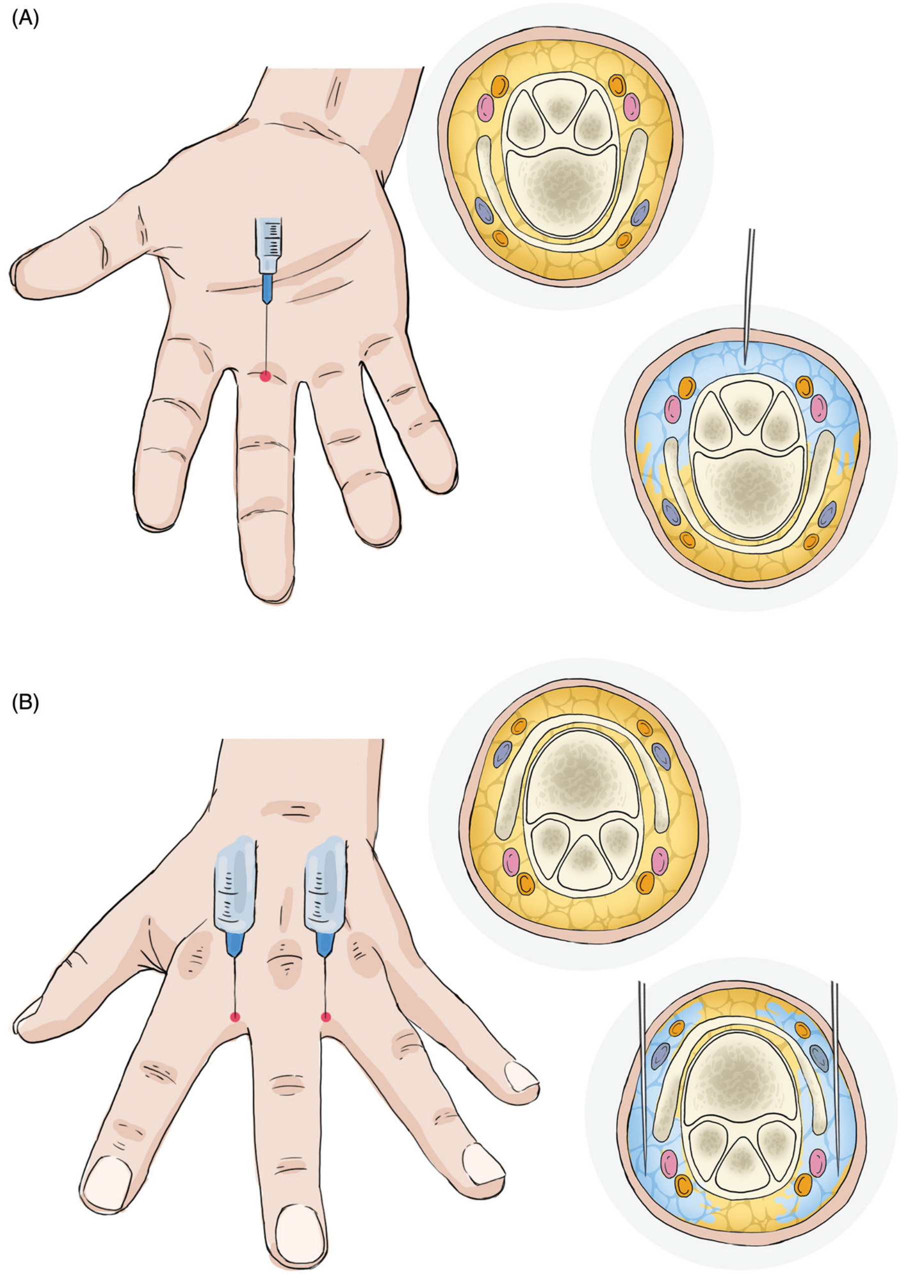


Figure 2. Comparison between volar and dorsal injections of digital block from the included studies. (A) Location of a volar injection for digital local anesthesia. (B) Location of a dorsal injection for digital local anesthesia.

anesthesia with a double-dorsal injection across studies under a random-effects model (RR: 1.55; 95% CI 1.09–2.20; $p = 0.014$; heterogeneity, $I^2 = 0\%$). In subgroup analysis on 10 min after injection, three pooled studies showed no difference in the RR for distal phalanx invalid anesthesia between the two groups across studies under a random-effects model (RR: 1.19; 95% CI 0.67–2.11; $p = 0.55$; heterogeneity, $I^2 = 0\%$). In subgroup analysis on 30 min after injection (only reported in one study), no significant difference was noted in the RR for distal phalanx invalid anesthesia (RR: 5.00; 95% CI 0.25–99.43; $p = 0.291$) (Figure 3(E)).

Pooled additional injection rate

Pooled data of four studies showed no significant difference in RR for distal phalanx invalid anesthesia with the need for additional injections with moderate heterogeneity across studies under a random-effects model (RR: 1.44; 95% CI 0.40–5.21; $p = 0.578$; heterogeneity, $I^2 = 56\%$) (Figure 3(F)).

Pooled patient preference

Pooled data of three studies showed a higher odds ratio in patient preference for a single-volar injection with high heterogeneity across studies under a random-effects model (odds ratio: 0.25; 95% CI 0.08–0.81; $p = 0.021$; heterogeneity, $I^2 = 79\%$) (Figure 3(G)).

Pooled adverse effects

Pooled data of seven studies showed no significant difference in RR with regards to adverse effects between double-dorsal and single-volar injections with low heterogeneity across studies under a random-effects model (RR: 1.01; 95% CI 0.40–2.53; $p = 0.578$; heterogeneity, $I^2 = 0\%$) (Figure 3(H)).

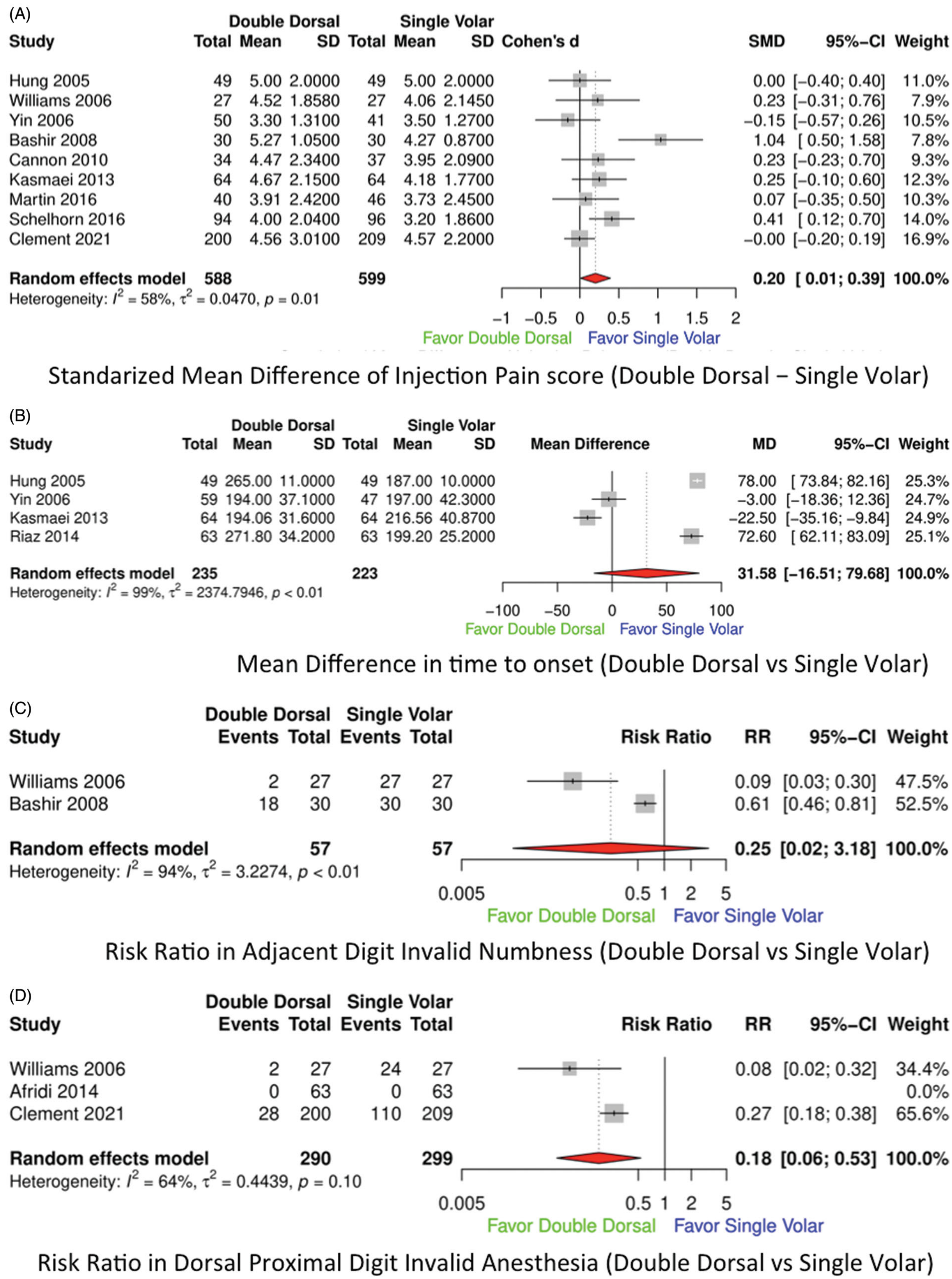
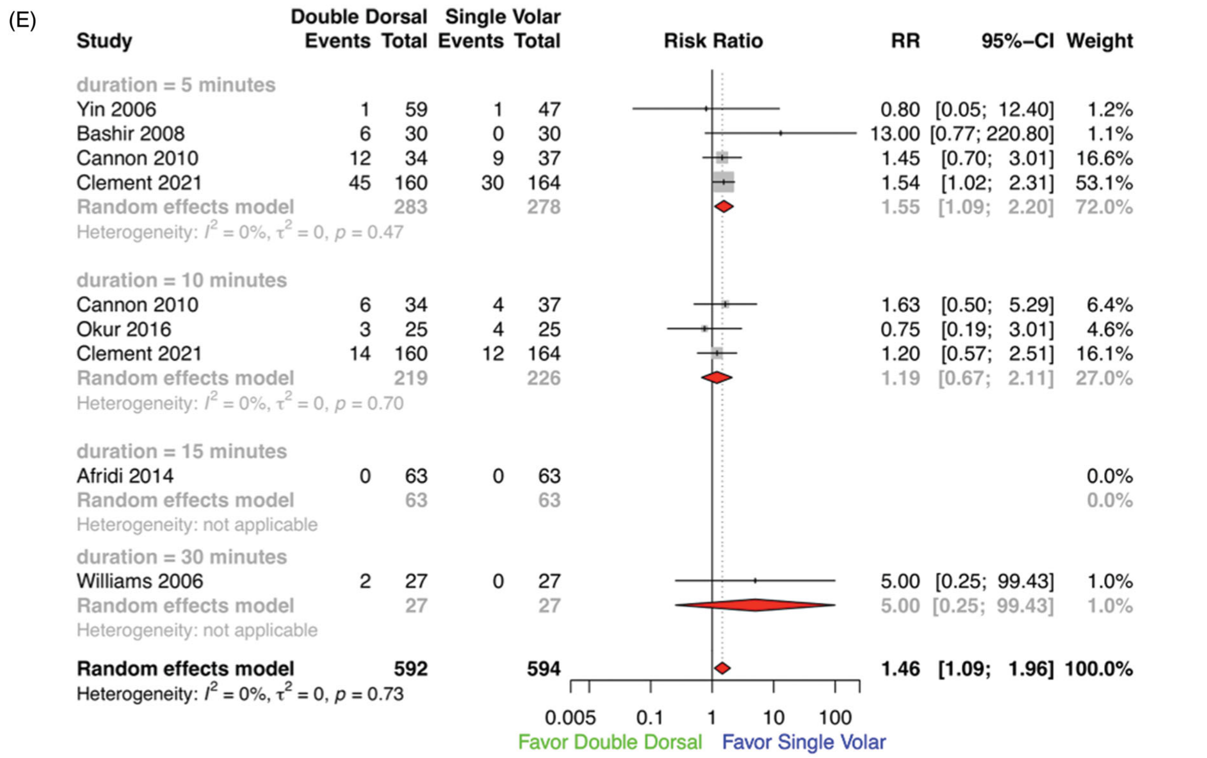
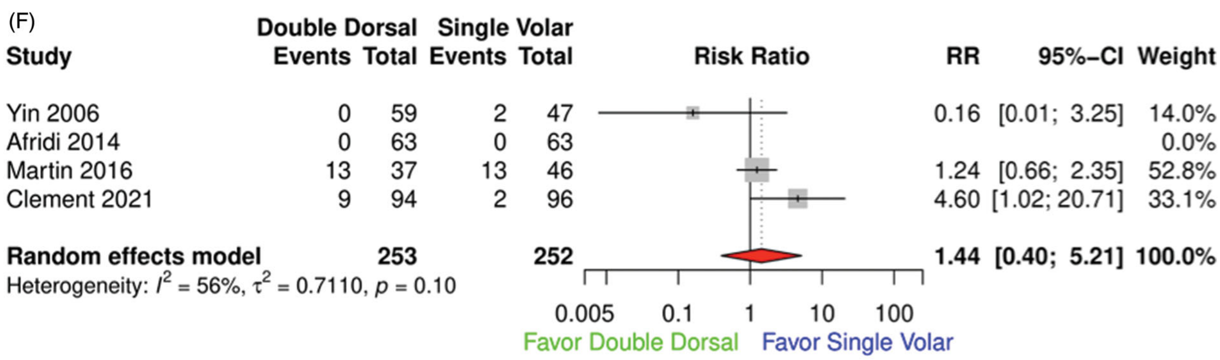


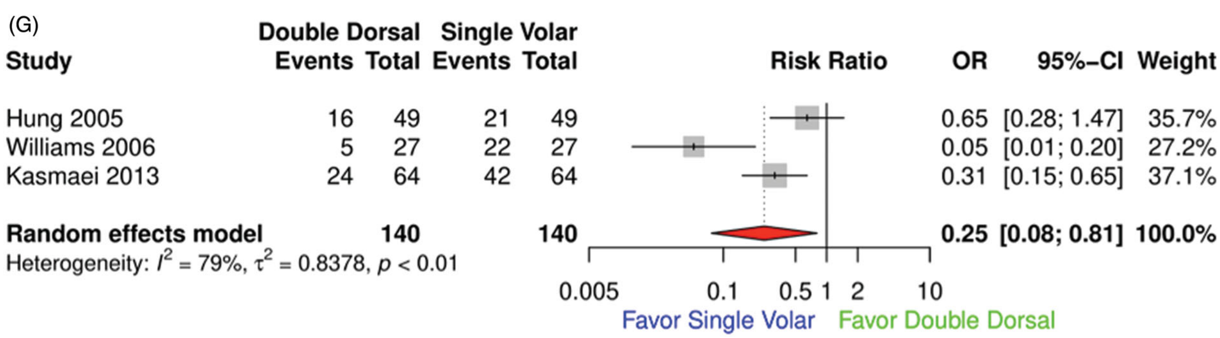
Figure 3. Forest plots of the primary outcomes. (A) Forest plot of the included studies comparing pain score during injection between volar and dorsal injections for digital anesthesia using a random effects model. (B) Forest plot of the included studies comparing time to onset of local anesthesia between volar and dorsal injections for digital anesthesia using a random effects model. (C) Forest plot of the included studies comparing adjacent digit invalid numbness between volar and dorsal injections for digital anesthesia using a random effects model. (D) Forest plot of the included studies comparing dorsal proximal digit invalid anesthesia with subgroup analysis of different time points between volar and dorsal injections for digital anesthesia using a random effects model. (E) Forest plot of the included studies comparing distal phalanx invalid anesthesia between volar and dorsal injections for digital anesthesia using a random effects model. (F) Forest plot of the included studies comparing additional injection rate between volar and dorsal injections for digital anesthesia using a random effects model. (G) Forest plot of the included studies comparing patient preference between volar and dorsal injections for digital anesthesia using a random effects model. (H) Forest plot of the included studies comparing adverse effects between volar and dorsal injections for digital anesthesia using a random effects model.



Risk Ratio in Distal Phalanx Invalid Anesthesia with subgroup analysis (Double Dorsal vs Single Volar)



Risk Ratio in Additional Injection Rate (Double Dorsal vs Single Volar)



Odds Ratio in Patient Preference(Double Dorsal vs Single Volar)

Figure 3. Continued

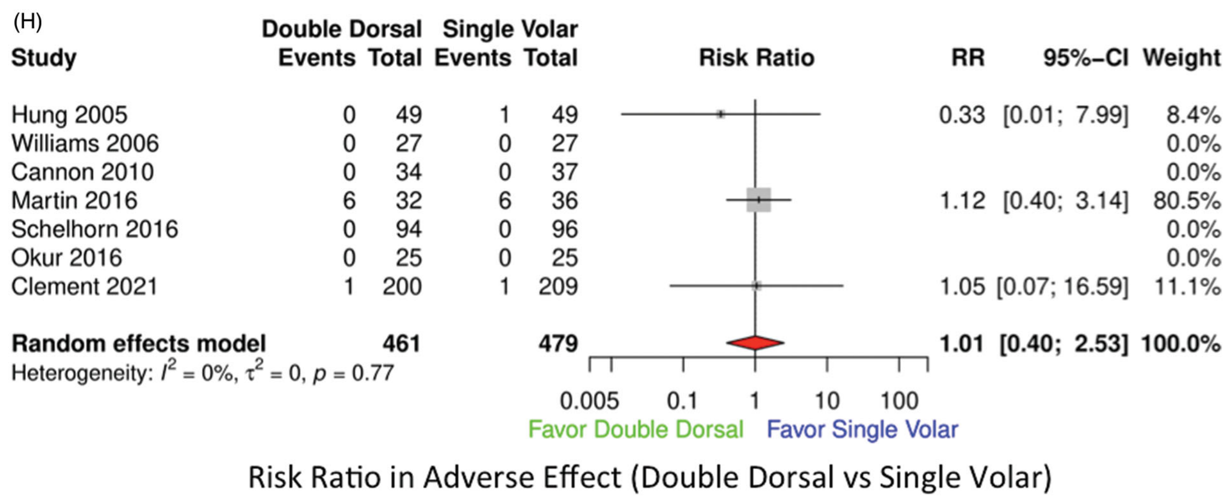


Figure 3. Continued

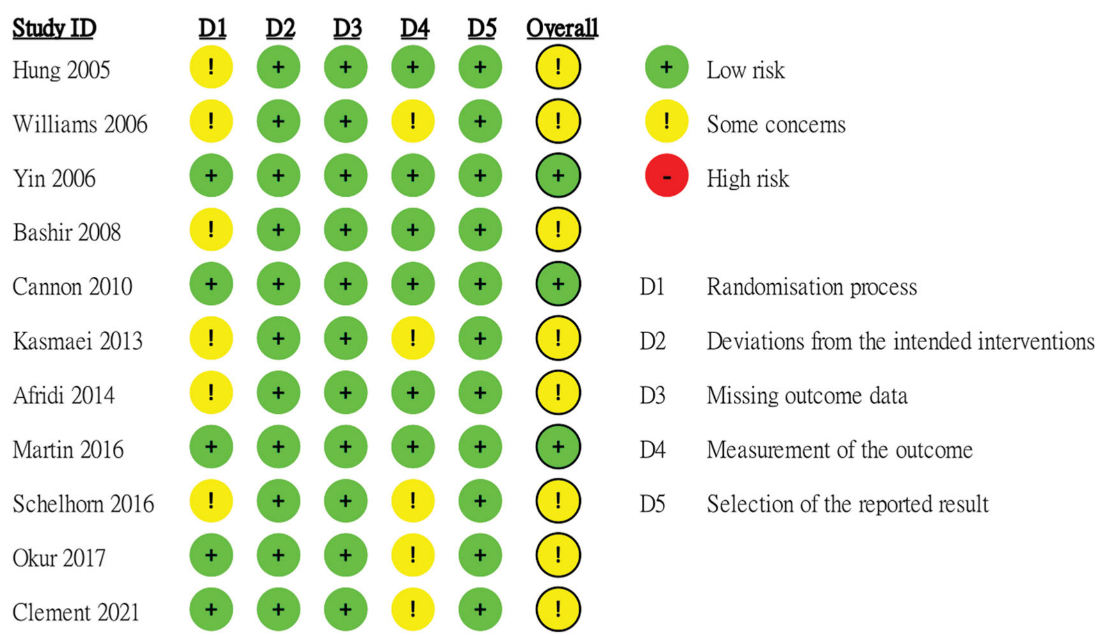


Figure 4. Risk-of-bias assessment. Risk-of-bias summary: Authors' regarding each risk-of-bias item for the included studies.

Study quality assessment

The quality of the included RCTs was assessed using the Cochrane risk-of-bias tool (RoB 2.0) [25]. The risk of bias of the studies is shown in Figure 4, with publication bias assessed using funnel plots as shown in Figure 5.

GRADE of evidence

The overall rating of certainty for both methods of local anesthesia was moderate, mainly due to concerns regarding the Inconsistency with some heterogeneity (Table 2).

Discussion

This systematic review and meta-analysis of 11 RCTs compared the effects of double-dorsal and single-volar subcutaneous injections, two local anesthesia techniques in hand surgery. Previous studies have shown that volar subcutaneous and classic double-dorsal injections are better than a transthecal approach with regard to injection pain [23,36]. However, no recent large-scale studies have compared double dorsal and single-volar subcutaneous injections. Moreover, previous studies have been limited by small pooled sample sizes, relatively narrow inclusion criteria, and possible imprecise data extraction.

The classic double-dorsal injection, first proposed by Braun and Harris [14], involves an injection on each side of the digit, and it has been used for a long time. In this review, the general approach was to inject 1-3 ml of local anesthesia into the base of the proximal phalanx on each side of the finger from the dorsal side. The reason for injecting the dorsal skin of the finger is because volar skin is considered to be more sensitive than dorsal skin [37]. The pooled meta-analysis of the 9 RCTs in the present study showed a statistically significantly higher painful sensation with a dorsal injection ($p = 0.041$), which contrasts with the previous hypothesis. The reason may result from two puncture sites of the double-dorsal injection and the more extended pathway from dorsal injection than the volar injection. The other method to evaluate the pain sensation of the skin is by assessing the

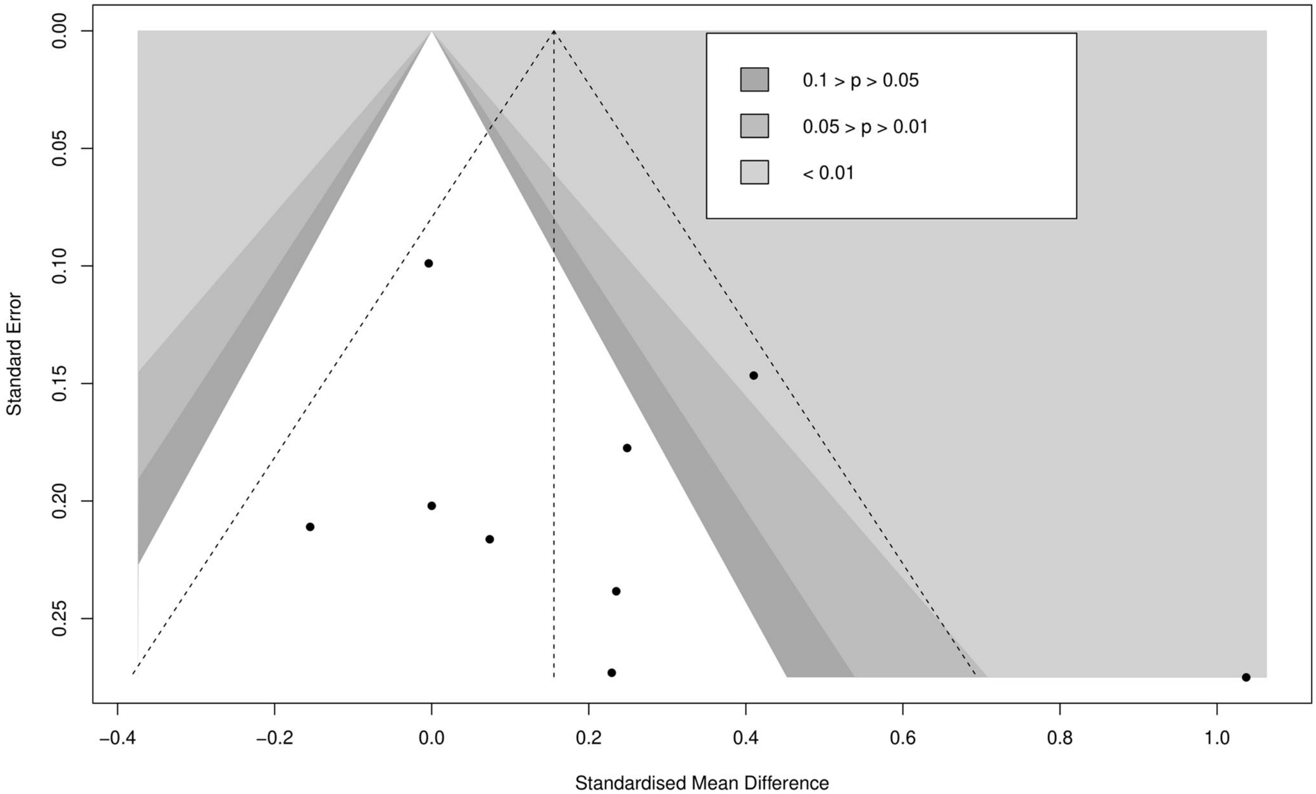


Figure 5. Contour-enhanced funnel plot. Funnel plot assessing publication bias of the included studies reporting the effect of single-volar subcutaneous and double-dorsal finger injections for digital block.

intraepidermal nerve fiber density (IENFD). The previous study showed that IENFD is higher in hairy skin than glabrous skin at the wrist level, but no study evaluated at the palm level yet [38]. Also, the other study found that the fingertip skin has more than twice the nerve fiber density in the papillary dermis than the volar skin of the palm [39]. These results may explain that volar injection has less pain than dorsal skin at the palm level, but further anatomical and histological studies were needed to verify it.

There are several approaches for volar local anesthesia. Chiu used one volar injection into the flexor tendon sheath, which acted as a delivery conduit of the local anesthetic to the digit [12]. Then, Harbison proposed a single-volar subcutaneous injection of local anesthetic into the palmar subcutaneous tissue above the flexor tendon sheath at the level of the first annular pulley [13]. In our systematic review, volar subcutaneous block was performed by subcutaneously injecting 2-3 ml of local anesthesia into the proximal flexion crease of the finger, the metacarpophalangeal joint, or the A1 pulley. Our results showed no statistically significant differences between the volar and dorsal approaches regarding onset time, adverse effects, and the need for additional injections. However, we found that the volar subcutaneous block failed to numb the dorsal side of the proximal phalanx compared to the dorsal block. The reason may result from the dorsal surface of the proximal fingers being mainly innervated by the superficial branch of the radial nerve and the dorsal cutaneous branch of the ulnar nerve [40,41], and volar subcutaneous injections may not numb these nerves. Therefore, when surgery is performed on the dorsal side of the proximal fingers, it is better to check before surgery whether or not the surgical area is numb. In addition, WALANT surgery can be performed using a volar cutaneous injection first and then waiting for at least 45 s before gradually injecting the local anesthesia from the first injection site to the dorsal skin area [37]. Using this method, the patient will feel pain from the first injection without further discomfort.

Besides the technique, many other factors can affect the subjective pain sensation when performing local anesthesia, including buffering the local anesthetic with sodium bicarbonate, warming the local anesthetic, using a small diameter needle, distraction, inserting the needle perpendicular to the skin, injecting very slowly, using a blunt-tipped cannula for rapid painless local anesthesia injection, and so on [21,37,42]. For the duration of the effect of local anesthetic, there is some adjuvant pharmaceutics that can prolong the duration, like dexmedetomidine, dexamethasone, clonidine, sodium bicarbonate, and Epinephrine [42–44]. All these methods and adjuvant pharmaceutics can help us to do better local anesthesia.

In this study, we excluded a study by Yin published in 2005, entitled "Single-injection digital block versus traditional digital block for local anesthesia in digital injury patients: A randomized controlled trial" due to an overlapping patient population with a more recent study also conducted by Yin which we did include for analysis [41]. In addition, the latest systematic review and meta-analysis published by Ito compared traditional two-injection dorsal digital block versus transthecal and subcutaneous single-injection digital block showed that three methods were equally effective [36]. However, Ito's study did not include three studies [30,33,35], and so it may not reflect adequate data for analysis.

Although our study provides the latest evidence regarding comparisons of the effect between single-volar subcutaneous and double-dorsal finger injections with local anesthesia for the digital block by a meta-analysis of RCTs. However, several limitations should be noted:

Table 2. GRADE assessment of included studies on outcome.

Certainty assessment							Summary of findings				
							Study event rates (%)			Anticipated absolute effects	
Participants (studies) Follow-up	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Overall certainty of evidence	With Single Volar Injection	With Double Dorsal Injection	Relative effect (95% CI)	Risk with Single Volar Injection	Risk difference with Double Dorsal Injection
Injection pain score											
1187 (9 RCTs)	Not serious	Serious	Not serious	Not serious	None	⊕⊕⊕◯ Moderate	599	588	–	–	SMD **0.2 SD higher** (0.01 higher to 0.39 higher)
Time to onset											
458 (4 RCTs)	Not serious	Serious	Not serious	Not serious	None	⊕⊕⊕◯ Moderate	223	235	–	The mean time to onset was **0**	MD **29.02 higher** (25.97 lower to 84.02 higher)
Adjacent digit invalid numbness											
114 (2 RCTs)	Not serious	Serious	Not serious	Serious	None	⊕⊕◯◯ Low	57/57 (100.0%)	20/57 (35.1%)	**RR 0.25** (0.02 to 3.18)	1,000 per 1,000	**750 fewer per 1,000** (from 980 fewer to 1,000 more)
Dorsal proximal digit invalid anaesthesia											
589 (3 RCTs)	Not serious	Not serious	Not serious	Serious	None	⊕⊕⊕◯ Moderate	134/299 (44.8%)	30/290 (10.3%)	**RR 0.18** (0.06 to 0.53)	448 per 1,000	**367 fewer per 1,000** (from 421 fewer to 211 fewer)
Distal phalanx invalid anaesthesia											
1186 (7 RCTs)	Not serious	Not serious	Not serious	Not serious	None	⊕⊕⊕⊕ High	60/594 (10.1%)	89/592 (15.0%)	**RR 1.46** (1.09 to 1.96)	101 per 1,000	**46 more per 1,000** (from 9 more to 97 more)
Additional injection rate											
505 (4 RCTs)	Not serious	Not serious	Not serious	Serious	None	⊕⊕⊕◯ Moderate	17/252 (6.7%)	22/253 (8.7%)	**RR 1.44** (0.40 to 5.21)	67 per 1,000	**30 more per 1,000** (from 40 fewer to 284 more)
Patient Preference											
280 (3 RCTs)	Not serious	Serious	Not serious	Not serious	None	⊕⊕⊕◯ Moderate	85/140 (60.7%)	45/140 (32.1%)	**OR 0.25** (0.08 to 0.81)	607 per 1,000	**328 fewer per 1,000** (from 497 fewer to 51 fewer)
Adverse effect											
940 (seven RCTs)	Not serious	Not serious	Not serious	Serious	None	⊕⊕⊕◯ Moderate	8/479 (1.7%)	7/461 (1.5%)	**RR 1.01** (0.40 to 2.53)	17 per 1,000	**0 fewer per 1,000** (from 10 fewer to 26 more)

CI: confidence interval; MD: mean difference; OR: odds ratio; RR: risk ratio; SMD: standardised mean difference.

1. The detailed procedure of the injection technique varied between studies. The needle size, the speed, path, and angle of injection, the temperature of medication, and different solutions for local anesthesia were heterogeneous or less mentioned. Among these studies, two studies (Cannon, 2010 and Schelhorn, 2016) used different kinds of local anesthesia (Bupivacaine and Mepivacaine) except lidocaine. These two local anesthesia agents have the different onset time and duration and may affect the outcome analysis. However, for each single study, the local anesthesia is the same between the single volar and double dorsal injection groups. The outcome measurement between these two groups still is reliable.
2. The patient sources varied among the studies, including volunteers, patients presented to the emergency department, and patients who received an operation in the operation theater. The different situations and places may affect the patients' subjective perception, resulting in possible bias. In addition, the different trauma types related to nerve injuries may also contribute to potential bias in the outcome measurement, such as adjacent digit invalid numbness, dorsal proximal digit invalid anesthesia, distal phalanx invalid anesthesia.
3. There was still some missing data, which hindered further interpretation.
4. Two studies compared different techniques in the same individual, resulting in possible bias since pain and satisfaction are subjective.
5. The injection itself cannot be double-blinded to avoid performance bias.

Further RCTs with more patients, blinded and objective measurements to decrease the possible bias are needed to verify our findings.

Conclusions

In this meta-analysis of RCTs, a volar injection was shown to be significantly less painful with higher patient satisfaction. A volar injection had a more negligible anesthetic effect over the dorsal side of the proximal finger. Both single-volar subcutaneous and double-dorsal injections provided similar onset time, adverse effects, and reinjection rate. However, high-quality RCTs with more cases are needed to verify our findings.

Author contributions

CHL contributed to manuscript writing, data collection, and statistical analysis. MHL contributed to manuscript writing and data collection. YTL contributed to revision and manuscript reviewing. CCH contributed to revision and manuscript reviewing. CHL contributed to revision and manuscript reviewing. SHC contributed to revision and manuscript reviewing. RWH contributed to manuscript writing, data collection, and statistical analysis.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix

MEDLINE/EMBASE/COCHRANE

(anesthe* OR anaesthe* OR analges* OR inject* OR block OR SIMPLE block OR SIMPLE technique OR SIMPLE injection) AND (palmar OR volar OR dorsal) AND (finger OR digit* OR thumb OR pollex OR dactyl)