

## SYSTEMATIC REVIEW/META-ANALYSIS

## Pain Management and Sedation

## Digital nerve blocks: A systematic review and meta-analysis

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Meetings: None

Grants: None

**Funding and support:** By JACEP Open policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see [www.icmje.org](http://www.icmje.org)). The authors have stated that no such relationships exist.

## Abstract

**Study objective:** Digital nerve blocks (DNBs) provide local anesthesia for minor procedures of the digits. Several DNB techniques have been described, but it is unclear which technique provides adequate anesthesia with the least pain. DNB techniques can be grouped into a dorsal approach, which requires 2 injections, versus 3 different types of volar approaches, which require a single injection. We performed a meta-analysis to compare DNB techniques with respect to time to anesthesia (TTA), duration of anesthesia (DOA), and pain of injection. We also reviewed data on degree and distribution of anesthesia and discuss the techniques preferred by study participants and clinicians performing injections.

**Data Sources:** We searched MEDLINE, EMBASE, and CENTRAL databases with terms "digital block," "digital nerve block," "local anesthetic," "local anesthesia," "lidocaine," and/or "bupivacaine."

**Study Selection:** Randomized controlled trials (RCTs) were prioritized, though high-quality prospective cohort studies were also eligible. All included studies evaluated DNB techniques or anesthetics. There were 23 papers (21 RCTs, 2 prospective descriptive studies) included.

**Data Extraction:** DNBs studied included dorsal ring block, traditional dorsal block, transthecal block, modified transthecal block, and volar subcutaneous digital blocks. Outcomes measured included TTA, DOA, pain of injection scores, and degree of anesthesia.

**Results:** Overall, mean TTA was 4.5 minutes (95% confidence interval [CI] 3.5, 5.6), mean DOA was 187 minutes (95% CI 104.3, 269.7), and mean pain score was 2.1 out of 10 (95% CI 1.3, 2.8) without significant differences between studies or techniques.

**Conclusions:** There were no significant differences in the outcomes of TTA, DOA, and pain of injection between different DNB techniques. Single-injection volar approaches may be preferred by participants and clinicians over dorsal approaches that require 2 injections, particularly with respect to pain. However, 2-injection dorsal approaches may have better coverage of the proximal dorsal surface based on degree and distribution of anesthesia.

Supervising Editor: Juan March, MD

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## 1 | INTRODUCTION

### 1.1 | Background

Finger injuries are common injuries presenting to the emergency department, with finger lacerations making up the majority of hand and wrist injuries in the United States between 2009 and 2018.<sup>1,2</sup> Digital nerve blocks are typically the standard of care in the treatment of finger injuries, during which injection with a local anesthetic provides analgesia needed to repair the injured digit. The challenge to emergency clinicians lies in performing effective blockade for various patterns of digital injuries with the least risk of complications and pain. Pediatric patients pose additional challenges because of variable digit sizes that limit generalizability, developmental ability to cooperate with procedures, and limited studies evaluating digital nerve block techniques in children.<sup>3</sup>

### 1.2 | Importance

Different approaches to the digital nerve block technique have been studied. Dorsal digital nerve blocks and ring blocks are the traditional techniques used and taught in medical education. However, these techniques require more than 1 injection and carry a theoretical risk of injury to the neurovascular bundle.<sup>4</sup> Alternative techniques include volar subcutaneous and transthecal approaches. Modifications of these alternative volar injections at different landmarks have also been developed to improve ease of performance. These alternative approaches may offer various advantages over traditional dorsal blocks, such as requiring only 1 injection, but the most effective and least painful digital nerve block technique has yet to be determined.

### 1.3 | Goals of this investigation

We reviewed the literature on different approaches to the digital nerve block and performed a meta-analysis on the available data to elucidate differences in outcome between techniques. The purpose of this study was to identify the most effective approach to the digital nerve block with respect to time to anesthesia (TTA), duration of anesthesia (DOA), and pain associated with injection. We also reviewed the data regarding degree of anesthesia and the preferences for different digital nerve block techniques among participants and practitioners.

## 2 | METHODS

### 2.1 | Selection of articles

We searched MEDLINE (1946 to August 2020), EMBASE (1947 to August 2020) and Cochrane Central Register of Controlled Trials (CENTRAL) (August 2020) databases with the following search terms: "digital block," "digital nerve block," "local anesthetic," "local anesthesia," "lidocaine," and "bupivacaine." Searches were limited to human subjects and the English language. The bibliographies of full-text arti-

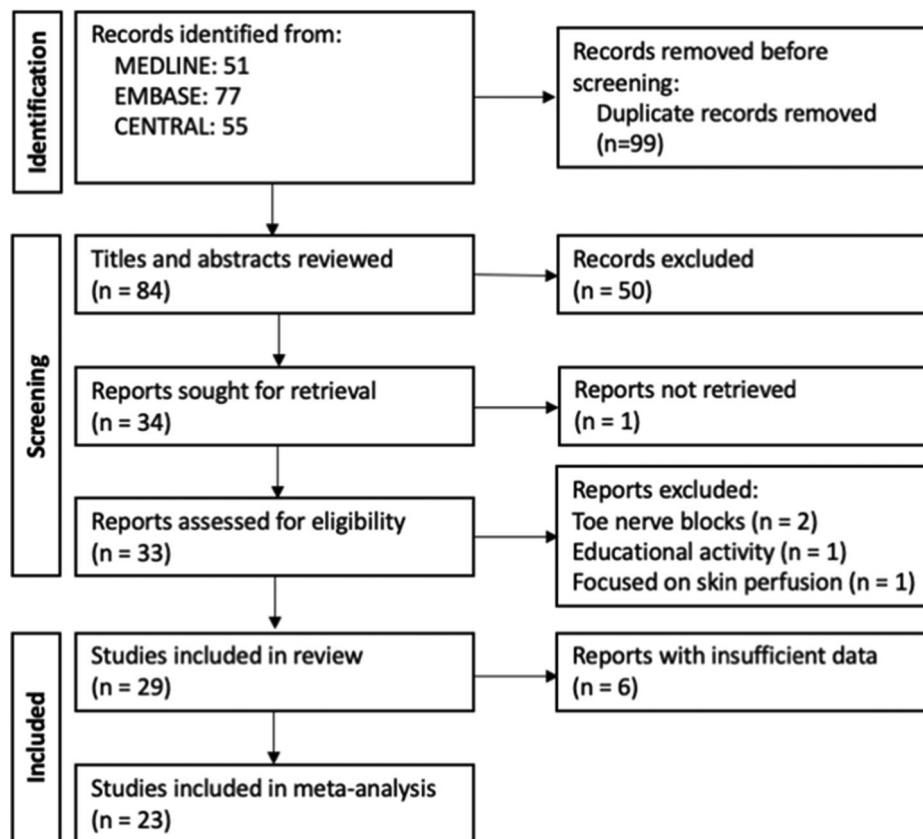
cles were also examined for studies that may have been missed in the preliminary searches. Titles and abstracts of the search were reviewed and excluded if the study did not investigate digital nerve blocks. We accepted randomized control trials (RCTs) evaluating digital blocks in children and/or adults, as well as prospective descriptive studies. Studies were included in our meta-analysis if they met the following criteria: (1) enrolled healthy volunteers or patients receiving a digital nerve block; (2) outcomes reported included time to onset of anesthesia, DOA, and/or pain scores on a numeric rating or visual analog scale; and (3) digital nerve blocks were performed by a trained medical practitioner. Studies that focused on toe nerve blocks were excluded. Studies that were unpublished, for which full-text articles could not be obtained, or that did not have data reported as the mean and SD or median and range were excluded from our meta-analysis. One additional article was published after our meta-analysis was completed but is included in our review and discussion of the literature.<sup>5</sup> A flow chart for identification and selection of studies for systematic review and meta-analysis is shown in Figure 1.

### 2.2 | Appraisal of article quality

Three investigators (TYB, TC, and EK) independently reviewed the full-text articles of digital nerve block studies for inclusion in the review by completing a data extraction form. Data included in the extraction form were author and citation, age of participants, study design, description of digital nerve block technique, anesthetics used, sample size, and outcomes data. Investigators discussed studies where there was disagreement until a consensus was reached. Upon quality appraisal of study designs, included studies were limited to RCTs and cohort studies that evaluated digital block techniques in terms of the outcomes of TTA, DOA, and pain associated with the digital block injections. Two investigators (TYB and EK) evaluated each study included in our meta-analysis for risk of bias, using the criteria described by Higgins et al.<sup>6</sup> As with inclusion of studies, when there was a disagreement in evaluation of bias, the investigators discussed until consensus was reached. This risk of bias tool was created for RCTs; thus some of the items did not apply to the 2 cohort studies included in our meta-analysis. Results were then placed in tabular format for examination (Figure 2).

### 2.3 | Digital block types

A total of 10 digital nerve block techniques (Table 1) were evaluated in the 23 papers included (Table 2). The 4 dorsal approaches, collectively called the dorsal digital blocks (DDB) are the dorsal ring block (DRB), traditional dorsal block (TDB), traditional dorsal block with additional injection (TDB+), and metacarpal block (MCB). The DRB, TDB, and TDB+ require at least 2 injections, but the MCB requires only 1 injection. The distal volar digital blocks (DVDB) include the modified transthecal block (MTTB) and combined modified transthecal block and subcutaneous block (MTTB-SCB), which involve an injection of the flexor tendon at palmar digital crease or mid-proximal phalanx. The only proximal volar digital block (PVDB) is the transthecal block (TTB)



**FIGURE 1** Flow chart for identification and selection of studies for systematic review and meta-analysis. Abbreviation: CENTRAL, Cochrane Central Register of Controlled Trials

in which anesthetic is injected in the flexor tendon at the distal palmar crease or A1-pulley. Finally, 3 blocks use a single subcutaneous digital block (SCDB) on the volar surface: single injection midline phalanx with lidocaine and epinephrine (SIMPLE), subcutaneous digital block (SCB), and subcutaneous digital block at the A1-pulley (SCB-A1-pulley) (Figure 3).

## 2.4 | Outcome measures

The outcomes of interest for our meta-analyses were mean TTA of the digit, mean DOA, and mean pain score on a visual analog or numeric rating scale. We also reviewed the literature on the degree and distribution of anesthesia and the preferences of study participants and clinicians for different digital nerve block techniques.

## 2.5 | Data synthesis and analysis

Relevant data from eligible studies were combined using meta-analysis methods based on linear mixed models.<sup>7</sup> For TTA, measurements were converted to minutes. For mean pain scores, values were converted to a 1–10 scale when a different pain scale had been used. Mean estimates for each outcome were provided in all the studies. In a few studies where SD were not reported but ranges were, we estimated

the SD by multiplying the mean by an overall coefficient of variation estimate obtained by using those studies that had both mean and SD available. Sensitivity analyses were performed by calculating overall mean estimates and confidence intervals (CIs) with and without the studies for which SD had to be estimated. We then conducted analyses on each outcome separately, followed by meta-regression to assess variation attributed to the different overall approaches (DDB, DVDB, PVDB, and SCDB). Although we report the outcome of DOA for digital nerve blocks using ropivacaine and bupivacaine from the literature, only data from digital nerve blocks that used lidocaine anesthetic were included in our statistical analysis to avoid confounding. A subanalysis of mean pain scores for subjects who received buffered lidocaine was also performed. Heterogeneity tests of treatment effects were conducted using Cochran's Q test and percentage of heterogeneity (denoted as I<sup>2</sup>) was calculated to quantify the amount of heterogeneity between the treatment effects beyond that from sampling error. All analyses were carried out using R mixmeta package version 1.2.0.

## 3 | RESULTS

The search identified 51 papers in MEDLINE, 77 in EMBASE, and 55 in the Cochrane Clinical Library (CENTRAL) database. After removal of duplicates, 84 titles and abstracts were screened. From these, 34

	RSG	AC	BPP	BOA	IOD	SR
Reichl 1987	+	?	+	+	+	+
Knoop 1994	+	-	-	-	-	+
Waldbillig 1995	+	-	+	?	+	+
Hill 1995	+	+	-	+	+	+
Low 1997	+	+	-	+	+	+
Keramidas 2004	-	-	-	+	+	+
Hung 2005	+	-	-	+	?	+
Chale 2006	+	+	-	+	+	+
Thomson 2006	+	+	+	+	+	+
Williams 2006	-	-	-	-	+	+
Yin 2006	+	+	-	+	+	+
Keramidas 2007	-	+	?	?	+	+
Bashir 2008	-	-	-	?	+	+
Alhelail 2009	+	+	+	+	+	+
Sonohata 2009	+	+	-	-	+	+
Waitayawinyu 2009	+	+	+	+	+	+
Antevy 2010	N/A	N/A	N/A	N/A	+	+
Cannon 2010	+	+	-	+	+	+
Sonohata 2012	-	-	-	?	+	+
Afridi 2014	-	-	-	+	+	+
Afridi 2015	N/A	N/A	N/A	N/A	+	+
Martin 2016	+	+	-	+	+	+
Okur 2017	+	+	-	-	+	+

**Key**

+	Low risk of bias
-	High risk of bias
?	Unclear risk of bias

**FIGURE 2** Risk of bias summary. Abbreviations: AC, allocation concealment; BOA, blinding outcome assessment; BPP, blinding participants and personnel; IOD, incomplete outcome data; N/A, not applicable due to prospective cohort study design; RSG, random sequence generation; SR, selective reporting

full-text articles were deemed eligible for more detailed review for potential inclusion. The most common reason for exclusion of studies from the final analysis was lack of focus on digital block technique. The final analysis yielded 21 RCTs and 2 prospective cohort studies (Figure 1). From these, we performed analyses on the following characteristics of different digital nerve blocks: TTA, DOA, and pain associated with injection. We also reviewed the data on the digital nerve block technique and the degree of anesthesia achieved, and the preferences of study participants and clinicians between 1- versus 2-injection techniques.

### 3.1 | Characteristics of studies

The age of participants in the studies included in the meta-analysis ranged from 7 to 86 years except for 1 study that focused on children less than 18 years old, including those less than 1 year old.<sup>3</sup>

Fifteen studies included a dorsal approach in at least 1 of their injection groups: 2 studies used the DRB,<sup>8,9</sup> 12 studies included the

TDB,<sup>10-21</sup> 1 study included the TDB+,<sup>22</sup> and 1 study included the MCB technique.<sup>10</sup> Eight studies used volar approaches to the digital nerve block: 6 included the TTB,<sup>12,13,21,23-25</sup> and 4 included the MTTB.<sup>3,24-26</sup> Thirteen studies included a single subcutaneous injection: 2 included the SIMPLE,<sup>15,17</sup> 9 included the SCB,<sup>16,18-20,24,25,27-29</sup> and 1 included the SCB-A1-pulley.<sup>23</sup> Nine studies focused on only 1 digital nerve block technique,<sup>3,8,9,11,22,26-29</sup> 12 studies compared 2 techniques,<sup>10,12-21,23</sup> and 2 studies compared 3 techniques.<sup>24,25</sup>

Twenty of the 23 studies included in our meta-analysis used lidocaine<sup>3,8-17,19-22,24-29</sup>. Seven of these studies had at least 1 group that used lidocaine with epinephrine,<sup>9,17,19,21,25,27,29</sup> 2 used buffered lidocaine,<sup>10,12</sup> 1 used lidocaine in combination with topical lidocaine-epinephrine-tetracaine,<sup>14</sup> and 1 mixed lidocaine 1:1 with radio-contrast.<sup>25</sup> Four studies used bupivacaine,<sup>8,9,18,27</sup> 1 used bupivacaine mixed with lidocaine,<sup>3</sup> and 1 study used ropivacaine.<sup>22</sup> Of the 9 studies that used only 1 digital nerve block technique, 2 compared lidocaine to bupivacaine,<sup>8,9</sup> 1 compared lidocaine to ropivacaine,<sup>22</sup> 1 compared different temperatures of lidocaine,<sup>11</sup> 1 compared different volumes of lidocaine,<sup>26</sup> and 2 were prospective cohort studies.<sup>3,29</sup>

**TABLE 1** Description of digital nerve block approaches and techniques

Digital nerve block type/approach	Digital nerve block technique	Description
Dorsal digital block (DDB)	Dorsal ring block (DRB)	Dorsal injection into web space at 2, 4, 8, and 10 o'clock in relation to bone. <sup>8,9</sup>
	Traditional dorsal block (TDB)	Dorsal injection into both radial and ulnar web spaces of phalanx. <sup>10-21</sup>
	Traditional dorsal block plus (TDB+)	Dorsal injection into both radial and ulnar web spaces of phalanx and over dorsum of proximal phalanx. <sup>22</sup>
	Metacarpal block (MCB)	Dorsal injection with needle angled 90 degrees 1 cm proximal to metacarpophalangeal joint midway, then advanced until at level lateral to the volar surface of the metacarpal heads or until resistance to the palmar aponeurosis felt. <sup>10</sup>
Distal volar digital block (DVDB)	Modified transthecal block (MTTB)	Volar approach injection at the palmar digital crease or mid-proximal phalanx penetrating both flexor tendons to bone, needle then withdrawn away from bone with gentle pressure on plunger of syringe, anesthetic flow occurs as the needle is in the flexor tendon sheath. <sup>3,24-26</sup>
	Modified transthecal block plus subcutaneous block (MTTB+SCB)	Volar approach injection at the palmar digital crease penetrating both flexor tendons to bone, needle then withdrawn away from bone, anesthetic flow occurs as the needle is in the flexor tendon sheath, 2.5 ml of anesthetic infused in sheath, and as needle is withdrawn, 0.5 ml injected into subcutaneous space. <sup>31</sup>
Proximal volar digital block (PVDB)	Transthecal block (TTB)	Volar approach injection at the distal palmar crease or A1-pulley, with needle angled at 45-degree angle directed distally. Needle puncture of skin then passed through the flexor tendon, needle withdrawn 1–2 mm after resistance met followed by injection of anesthetic into tendon sheath. <sup>12,13,21,23-25</sup>
Subcutaneous digital block (SCDB)	Subcutaneous block (SCB)	Volar approach injection at the palmar digital crease with infusion of anesthetic into the subcutaneous tissue. <sup>16,18-20,24,25,27-29</sup>
	Subcutaneous block-A1-pulley (SCB-A1-pulley)	Volar approach with subcutaneous injection superficial to the A1-pulley. <sup>23</sup>
	Single injection in midline of phalanx with lignocaine and epinephrine (SIMPLE)	Volar approach with subcutaneous injection in midline, just short of proximal flexion crease of the finger. <sup>15,17</sup>

Sensitivity analyses comparing the mean estimates and 95% CIs when all studies were included versus only the studies reporting SD revealed similar estimates for TTA of 4.5 minutes (95% CI [3.5, 5.6]) vs 4.2 minutes (95% CI [3.2, 5.1]) and pain scores of 3.3 (95% CI [2.9, 3.8]) vs 3.4 (95% CI [2.8, 3.9]), but a greater difference for DOA of 187.0 minutes (95% CI [104.3, 269.7]) vs 130.5 minutes (95% CI [72.5, 188.6]). There was also significant heterogeneity among the different studies ( $P < 0.05$ ,  $I^2 > 90\%$ ) for TTA, DOA, and pain of injection. This heterogeneity was present regardless of whether the nerve blocks were grouped into the 4 main block types (DDB, DVDB, PVDB, and SCDB).

### 3.2 | Risk of bias

The risk of bias within studies is summarized in Figure 2. The 2 prospective cohort studies were included in this summary figure although most of the criteria for assessing risk of bias are not applicable to that study design. The use of random sequence generation and allocation concealment was varied among studies. Many studies attempted to blind participants as to which injection technique was used by asking them to look away during injection. However, in most cases, it was not possi-

ble to blind participants and personnel to the injection technique. Many studies covered up the injection sites to blind the person measuring outcomes as to which injection was performed. Most studies provided complete data and were not selective in their reporting of outcomes.

### 3.3 | TTA

Seventeen studies reported TTA.<sup>3,8-10,12-14,16,19,21-26,28,29</sup> Most studies measured TTA by pinprick testing by an investigator over the distal portion of the digits.<sup>3,8-10,12-14,16,19,21-24,26,29</sup> In 2 studies, participants performed pinprick testing on themselves every 10 seconds for up to 60 minutes.<sup>25,28</sup> Three studies tested sensation to light touch in addition to pinprick.<sup>23,24,26</sup> There was considerable variability in the areas of the digit tested. Several studies did not specify which distal surface of the finger was tested or tested only the distal finger pulp.<sup>8,9,13,21-23,28</sup> Chale et al tested sensation at the wound edges on the digits.<sup>14</sup> Two studies specifically tested only the radial and ulnar surfaces of the middle and distal phalanges,<sup>10,12</sup> 1 tested only the palmar and dorsal surfaces,<sup>24</sup> and 4 studies tested the radial, ulnar, palmar, and dorsal surfaces of the digits.<sup>3,16,19,25,29</sup> The frequency of pinprick testing also



**TABLE 2** Digital nerve block studies included in meta-analysis

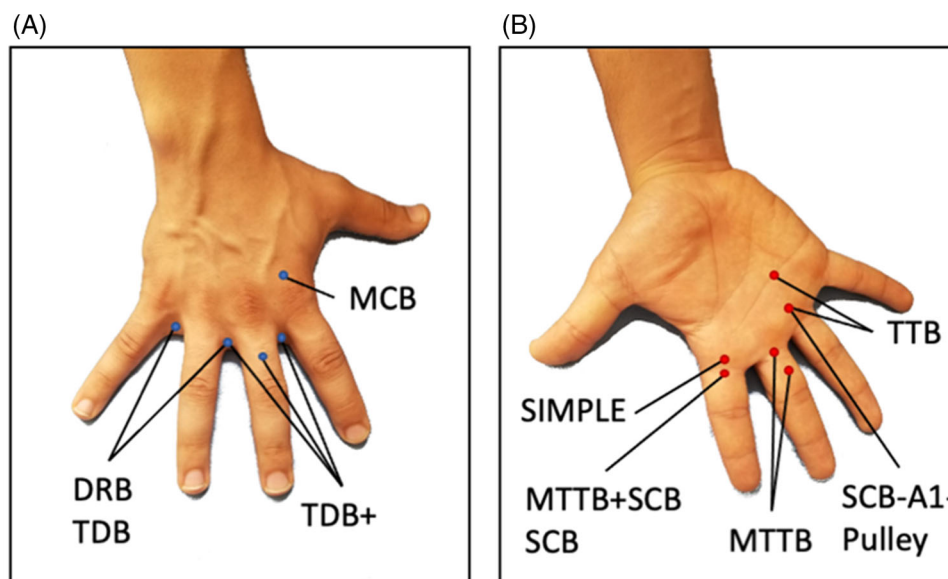
Study, Year	Participants, age	Design	Anesthetic(s)	Block(s)	Outcome measures and results (mean [standard deviation or range])		
					Time to anesthesia (minutes)	Duration of anesthesia (minutes)	Degree of anesthesia
Reichl, 1987	53 patients, 16–70 years	RCT	5 ml lidocaine 1% vs bupivacaine 0.5%	DRB	5.8 (5–10) vs 11.2 (8–20)	59.6 (28.7) vs 476 (277)	6/24 rr vs 0/29 rr
Knoop, 1994	30 patients, 19–64 years	RCT	2 ml buffered lidocaine 2%	TDB vs MCB	2.82 (1.01) vs 6.35 (2.94)	NR	1/30 inc, 1/30 rr vs 7/30 inc, 4/30 rr
Waldbillig, 1995	20 volunteers, 21–36 years	RCT	1.5 ml 21°C vs 42°C lidocaine 2%	TDB	NR	NR	NR
Hill, 1995	31 volunteers, 18–45 years	RCT	2 ml buffered lidocaine 1%	TDB vs TTB	2.53 (0.11) vs 3.13 (0.18)	NR	NR
Low, 1997	20 volunteers	RCT	2 ml lidocaine 1%	TTB vs SCB-A1-pulley	8.0 (3.6) vs 6.8 (2.9)	49.2 (11.5) vs 50 (12)	10/20 inc, 2/20 failed vs 11/20 inc, 0/20 failed
Keramidas, 2004	50 patients, 18–72 years	RCT	2 ml lidocaine 1%	TDB vs TTB	1.67 (0.1) vs 2.75 (0.15)	NR	NR
Hung, 2005	50 volunteers, 18–80 years	RCT	2 ml lidocaine 2%	SCB vs TTB vs MTTB	3.12 (0.17) vs 2.93 (0.17) vs 4.42 (0.18)	NR	NR
Chale, 2006	55 patients, 11–82 years	RCT	1–2 ml lidocaine 1% vs lidocaine 1% with 1–2 ml LET	TDB vs local injection	7.7 (4.6–10.9) vs 1.9 (0.8–3.0)	NR	1/28 rr vs 0/27 rr
Thomson, 2006	30 volunteers	RCT	1.8 ml lidocaine 2% vs lidocaine 2% with epi vs bupivacaine 0.5%	SCB	NR	294 (252–336) vs 624 (564–684) vs 1494 (1344–1644)	NR
Williams, 2006	27 volunteers, 23–51 years	RCT	1.8 ml lidocaine 2%	TDB vs SIMPLE	NR	305 (NR) vs 417 (NR)	2/27 inc vs 24/27 inc
Yin, 2006	91 patients	RCT	3 ml lidocaine 1% for TDB, 2 ml lidocaine 1% for SCB	TDB vs SCB	3.23 (0.62) vs 3.28 (0.71)	NR	NR

(Continues)

TABLE 2 (Continued)

Outcome measures and results (mean [standard deviation or range])								
Study, Year	Participants, age	Design	Anesthetic(s)	Block(s)	Time to anesthesia (minutes)	Duration of anesthesia (minutes)	Degree of anesthesia	Pain of injection
Keramidas, 2007	70 patients, 19–72 years	RCT	2.5 ml ropivacaine 0.75% vs lidocaine 2%	TDB+	4.5 (0.50) vs 1.3 (0.23)	1290 (85.14) vs 144 (48.78)	NR	NR
Bashir, 2008	30 patients	RCT	2 ml lidocaine 2% with epi	TDB vs SIMPLE	NR	304 (NR) vs 387 (NR)	6/30 inc vs 9/30 inc	5.27 (4-7) vs 4.27 (3-6)
Alhelail, 2009	12 volunteers, 18 years and older	RCT	1 ml lidocaine 1% with epi vs bupivacaine 0.5%	DRB	3.5 (3.0-8.0) vs 3.3 (3.0-8.0)	321 (228-463) vs 701 (245-913)	NR	2.6 (0.4-5.4) vs 4.05 (1.0-7.1)
Sonohata, 2009	15 volunteers, 25–37 years	RCT	1.5 ml lidocaine 2% with 1.5 ml lotrolan X-ray contrast	TTB vs MTTB vs SCB	7.8 (2.6) vs 19.4 (21.6) vs 6.3 (1.8)	68.9 (40.2) vs 34 (20.6) vs 58 (19.5)	NR	NR
Waitayawinyu, 2009	45 volunteers, 25–52 years	RCT	1 ml vs 2 ml vs 3 ml lidocaine 1%	MTTB	NR vs 7.3 (NR) vs 1.5 (NR)	NR vs 22 (NR) vs 45.7 (NR)	NR	1.3 (0.9) vs 2.6 (1.3) vs 2.9 (1.5)
Antevy, 2010	48 patients, 0.7-17.5 years	PC	0.75-3 ml of 1:1 lidocaine 1% with bupivacaine 0.5%	MTTB	1.88 (0.41)	NR	3/50 inc	NR
Cannon, 2010	76 patients, 19–89 years	RCT	2-3 ml bupivacaine 0.5%	TDB vs SCB	NR	NR	6/34 inc vs 4/37 inc	4.47 (2.34) vs 3.95 (2.09)
Sonohata, 2012	9 volunteers, 20–37 years	RCT	3 ml lidocaine 1% vs lidocaine 1% with epi	SCB	4.0 (0.85) vs 2.8 (0.83)	48.1 (23.5) vs 280.7 (23.5)	NR	NR
Afridi, 2014	126 patients, 17–60 years	RCT	3 ml lidocaine 2% with epi	TDB vs SCB	4.53 (0.57) vs 3.32 (0.42)	299.52 (28.82) vs 271.9 (29.34)	NR	NR
Afridi, 2015	60 patients, 16–61 years	PC	3 ml lidocaine 2% with epi	SCB	3.32 (0.42)	271.9 (29.33)	NR	NR
Martin, 2016	86 patients, > 18 years	RCT	2-3 ml lidocaine 1%	TDB vs SCB	NR	3.91 (2.59) vs 3.73 (2.45)	16/40 inc vs 13/46 inc	NR
Okur, 2017	50 patients, 19–86 years	RCT	3 ml lidocaine 2% with epi	TDB vs TTB	2.0 (1.5-3.5) vs 3.0 (2.0-5.0)	NR	3/26 rr vs 4/26 rr	3 (1.25-4.75) vs 3.5 (2.25-5.5)

Abbreviations: DRB, dorsal ring block; inc, incomplete anesthesia; LET, lidocaine-epinephrine-tetracaine; vs, versus; MCB, metacarpal block; MTTB, modified transthecal block; NR, not reported; PC, prospective cohort; RCT, randomized controlled trial; rr, required rescue; SCB, subcutaneous digital block; SCB-A1-pulley, subcutaneous digital block superficial to A1 pulley; SIMPLE, single injection in midline of phalanx with lignocaine and epinephrine; TDB, traditional dorsal block; TDB+, traditional dorsal block + injection over dorsum of proximal phalanx; TTB, transthecal digital block; epi, epinephrine.



**FIGURE 3** Anatomic locations of digital nerve block techniques. Abbreviations: DRB, dorsal ring block; MCB, metacarpal block; MTTB, modified transthecal block; MTTB+SCB, modified transthecal block combined with subcutaneous digital block; SIMPLE, single injection in midline of phalanx with lignocaine and epinephrine; SCB, subcutaneous digital block; SCB-A1-pulley, subcutaneous digital block superficial to A1 pulley; TDB, traditional dorsal block; TDB+, traditional dorsal block + injection over dorsum of proximal phalanx; TTb, transthecal digital block

varied widely, ranging between every 10 seconds to every 2 minutes with the exception of 1 study that tested at 2, 5, and 10 minutes, and then every 10 minutes after injection.<sup>23</sup> Our meta-analysis found 1 outlier in an MTTB injection group that had a longer TTA, but otherwise there was little variation in TTA with respect to digital nerve block technique (Figure 4A). Overall, reported onset of action was highly variable and dependent on anesthetic type and anesthetic volume. Fastest onset of anesthesia reported was an average of 72 seconds (1.2 minutes) on the volar side followed by 90 seconds (1.5 minutes) on the dorsal side of the digit using the MTTB with infiltration of 3 ml of 1% lidocaine at room temperature.<sup>26</sup> The longest TTA, a total of 1164 seconds (19.4 minutes), was observed in a group of subjects receiving the MTTB injection with 1.5 ml of 2% lidocaine and 1.5 ml of radio-contrast.<sup>25</sup> The mean TTA of the 4 main digital nerve block approaches is shown in Figure 4B. Digital nerve blocks using the SCDB approach had the shortest mean TTA at 247 seconds (4.12 minutes), whereas DVDB approaches took an average of 512.1 seconds (8.55 minutes) for TTA (Figure 4B).

Volume of injection was not specifically analyzed as a factor affecting TTA in our meta-analysis. Waitayawinyu et al. examined the effect of lidocaine dose on TTA on 45 subjects found that injection of 1, 2, or 3 ml of 1% lidocaine via MTTB yielded no anesthesia, anesthesia in 7.3 minutes, or anesthesia in 1.5 minutes, respectively.<sup>26</sup> A different study directly examined the effect of epinephrine as an adjunct to lidocaine on TTA in 9 subjects. They found that 3 ml of 1% lidocaine with 1:100,000 epinephrine resulted in a mean TTA of  $2.8 \pm 0.83$  minutes, which was significantly shorter compared to  $4.0 \pm 0.85$  minutes for fingers injected with the same volume of 1% lidocaine alone ( $P < 0.05$ ).<sup>28</sup>

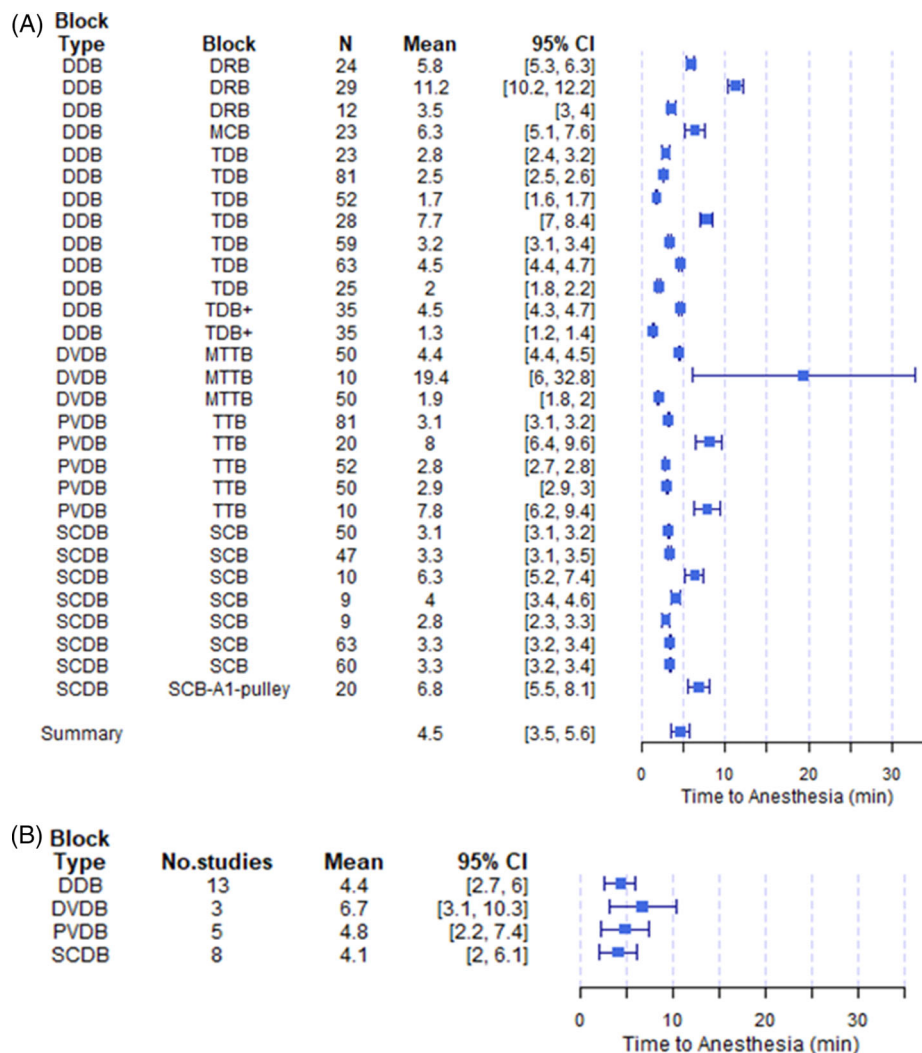
### 3.4 | DOA

Twelve studies reported DOA.<sup>8,9,14,15,17,19,22,23,25,26,28,29</sup> However, for 3 of those studies, DOA data could not be included in our meta-analysis because range or SDs were not reported.<sup>15,17,26</sup> We also excluded injections with bupivacaine or ropivacaine from our analysis of DOA because of known differences in the pharmacokinetics of these anesthetics compared to lidocaine. Studies used different methods for measuring DOA. Seven studies asked subjects to report when pain or pain to pinprick first returned,<sup>8,9,17,19,26,28,29</sup> whereas 2 studies asked subjects to report the time when they regained normal sensation in the fingertip,<sup>22,27</sup> and 3 studies recorded DOA based on when subjects reported normal sensation of the entire digit.<sup>15,23,25</sup>

Our meta-analysis of different injection techniques using lidocaine revealed an overall mean DOA of 187 minutes (95% CI: [104.3, 269.8] minutes) with significant variability even between studies using the same digital nerve block technique (Figure 5). Much of this variability could be explained by differences in DOA with lidocaine alone versus lidocaine with epinephrine. For example, the dorsal ring block had a mean DOA of 59.6 minutes in a study that used 1% lidocaine alone,<sup>8</sup> but a mean DOA of 321 minutes in a study that used 1% lidocaine with epinephrine.<sup>9</sup> However, 1 study using lidocaine with epinephrine for SCB injection found a mean DOA of 624 minutes<sup>27</sup> whereas the remaining studies that used the same anesthetic and injection technique found mean DOAs ranging from 272 to 281 minutes.<sup>19,28,29</sup> The shortest mean DOA included in our meta-analysis was 34 minutes using the MTTB injection of 2% lidocaine.<sup>28</sup>

We did not include data from bupivacaine or ropivacaine in our statistical analysis of DOA because these anesthetics had a longer





**FIGURE 4** Time to anesthesia (TTA) (seconds). (A) TTA for digital nerve blocks using lidocaine. (B) TTA for each of the 4 main block types/approaches using lidocaine. *N* = number of blocks. Abbreviations: CI, confidence interval; DDB, dorsal digital block; DRB, dorsal ring block; DVDB, distal volar digital block; MCB, metacarpal block; MTTB, modified transthecal block; PVDB, proximal volar digital block; SCB, subcutaneous block; SCB-A1-pulley, subcutaneous digital block superficial to A1 pulley; SCDB, subcutaneous digital block; TDB, traditional dorsal block; TDB+, traditional dorsal block + injection over dorsum of proximal phalanx; TTB, transthecal digital block

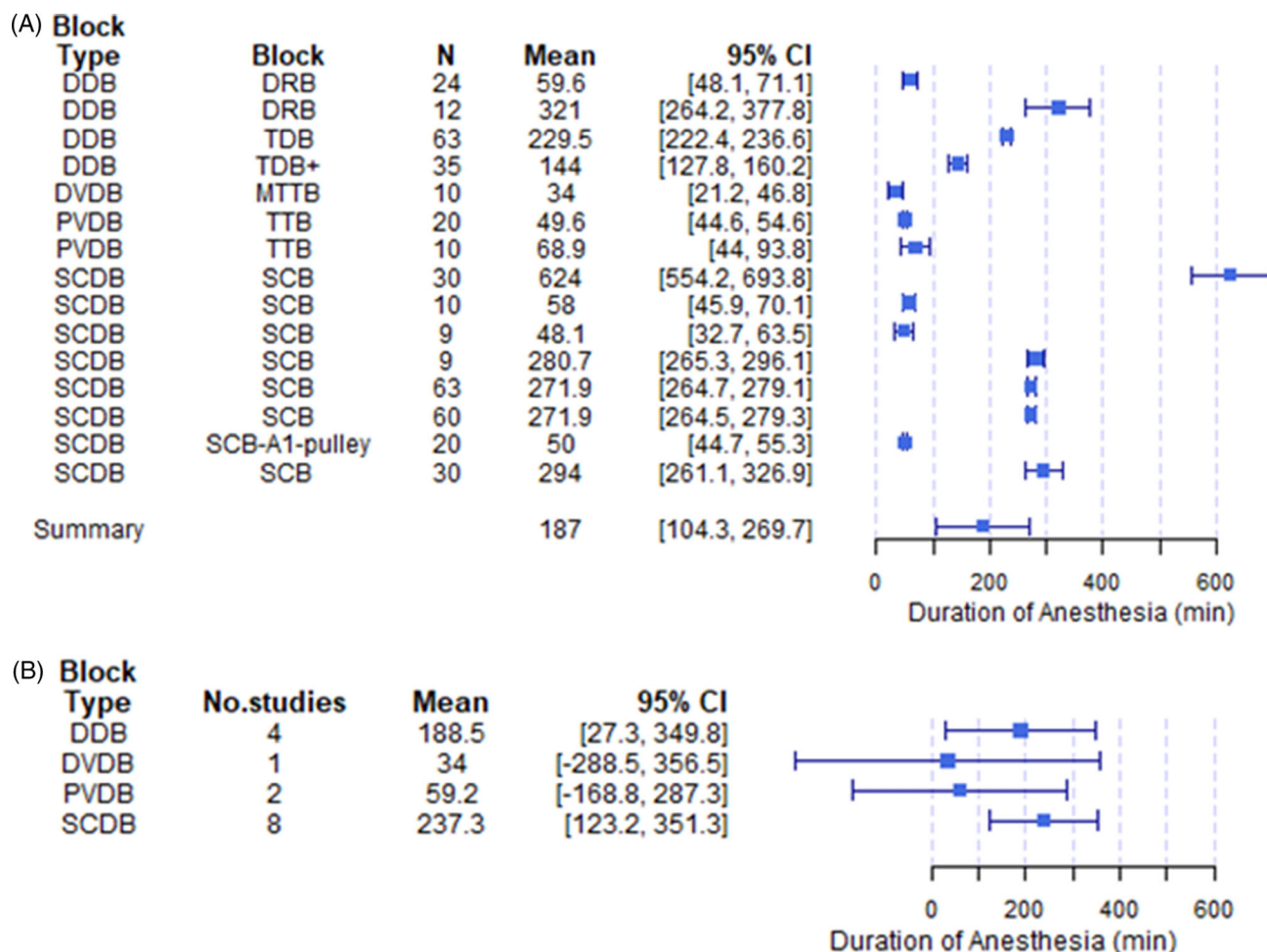
duration of action compared to lidocaine regardless of digital nerve block technique. When injected via TDB, ropivacaine lasted almost 9 times longer than lidocaine (1290 versus 144 minutes).<sup>22</sup> Bupivacaine also lasted at least twice the duration as lidocaine alone.<sup>8,9</sup> Using a DRB, 1 study found a median DOA of 701 minutes with bupivacaine versus 321 minutes of anesthesia with lidocaine.<sup>9</sup> Similarly, another study using the DRB found a mean DOA of 476 minutes with bupivacaine versus 60 minutes with lidocaine.<sup>8</sup> With the MTTB, 1 study found mean DOAs of 1494, 294, and 624 minutes were reported for 0.5% bupivacaine, 2% lidocaine, and 2% lidocaine with 1:100,000 epinephrine, respectively.<sup>27</sup> Importantly, this study measured DOA from the onset of anesthesia until the distal finger had completely normal sensation, which was a stricter definition of return of sensation compared to other studies.<sup>27</sup>

Finally, as with onset of action, there does appear to be a similar dose-dependent effect of anesthetic with regard to DOA. Using

1% lidocaine via the MTTB technique, injections of 1 ml yielded no anesthesia, 2 ml yielded anesthesia for 22 minutes, and 3 ml yielded anesthesia for 43 minutes.<sup>26</sup>

### 3.5 | Degree and distribution of anesthesia

Our literature search yielded 13 studies with data on the distribution or success of anesthesia achieved.<sup>3,8,10,14,15,17,18,20,21,23,30-32</sup> We did not perform meta-analysis on degree of anesthesia because of heterogeneity in the way it was reported. Three studies used the need for additional injection of anesthetic to define failure of the nerve block.<sup>10,20,21</sup> Other studies used predefined time points at which sensation would be tested to determine injection efficacy. Three studies used 5 minutes,<sup>3,16,17</sup> 1 study used 10 minutes,<sup>18</sup> another study used 15 minutes,<sup>19</sup> 2 studies used 30 minutes,<sup>14,15</sup> and 1 study used



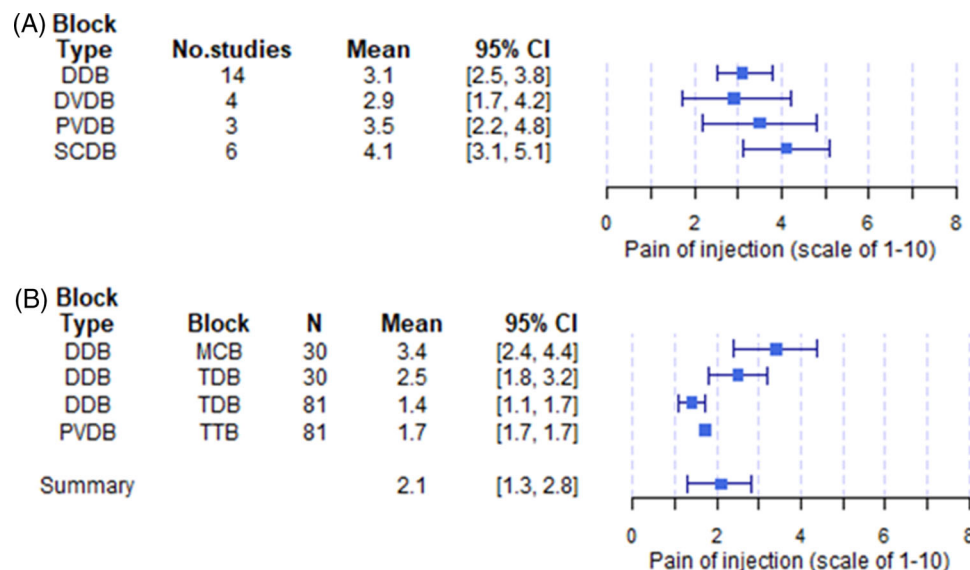
**FIGURE 5** Duration of anesthesia (DOA). (A) DOA for digital nerve blocks using lidocaine. (B) DOA for each of the 4 main block types/approaches using lidocaine. *N* = number of blocks. Abbreviations: CI, confidence interval; DDB, dorsal digital block; DRB, dorsal ring block; DVDB, distal volar digital block; MTTB, modified transthecal block; PVDB, proximal volar digital block; SCB, subcutaneous block; SCB-A1-pulley, subcutaneous digital block superficial to A1 pulley; SCDB, subcutaneous digital block; TDB, traditional dorsal block; TDB+, traditional dorsal block + injection over dorsum of proximal phalanx; TTB, transthecal digital block

60 minutes to define anesthesia failure.<sup>25</sup> One study mapped the distribution of anesthesia for each digital nerve block performed.<sup>15</sup> Two studies used predefined zones to pinprick test over time to assess distribution of anesthesia.<sup>25,33</sup> One study divided each digit by the distal, middle, and proximal phalanxes and then divided each phalanx into palmar and dorsal areas.<sup>25</sup> The other study divided each digit further into palmar, dorsal, radial, and ulnar aspects, resulting in 12 total zones.<sup>33</sup> Of studies that reported distribution of anesthesia, the traditional dorsal block resulted in reliable anesthesia of the proximal dorsal phalanx, whereas volar digital nerve block approaches did not consistently provide anesthesia over the dorsal aspect of the digits.<sup>15,25,33</sup>

The TDB was evaluated in 6 studies, and in 4 of those studies, the TDB resulted in a better percentage of complete anesthesia compared to volar techniques.<sup>10,15,21,33</sup> However, 3 studies reported a higher percentage of injections with incomplete anesthesia or needing rescue injection when using the TDB versus the SIMPLE,<sup>17</sup> TTB,<sup>32</sup> or SCB.<sup>20</sup>

A small double-blinded RCT of 20 volunteers comparing the TTB with SCB found that 10 out of 20 digits receiving TTBs had incomplete anesthesia, and 2 out of 20 of those digits had failure of anesthesia compared to 11 out of 20 digits receiving SCBs with incomplete anesthesia and no digits with failure to anesthetize.<sup>23</sup> Other studies also found that SCDBs were unable to achieve anesthesia of the proximal dorsal phalanx.<sup>15,28</sup> Similarly, findings of incomplete anesthesia of the proximal dorsal phalanx were reported in studies that evaluated the MTTB.<sup>25,31</sup> One study that evaluated the MTTB in pediatric patients reported a 94% success rate with 47/50 blocks resulting in successful anesthesia of the blocked digits.<sup>3</sup> Volar subcutaneous approaches had variable results in complete anesthesia, ranging from 11%–89%.<sup>15,17,18,23,25,28,31</sup>

There is a positive and reproducible dose-dependent effect of lidocaine on degree of anesthesia. Waitayawinyu et al showed that 2 or 3 ml of 1% lidocaine injected by MTTB resulted in a significantly greater degree of anesthesia compared to 1 ml.<sup>26</sup> There also appears to be improved anesthesia with increased concentration of



**FIGURE 6** Pain of injection. (A) Pain of injection between the 4 main types of digital nerve blocks regardless of anesthetic used. (B) Subanalysis of pain of injection for studies that specifically used buffered lidocaine. *N* = number of blocks. Abbreviations: CI, confidence interval; DDB, dorsal digital block; DVDB, distal volar digital block; MCB, metacarpal block; PVDB, proximal volar digital block; SCDB, subcutaneous digital block; TDB, traditional dorsal block; TTB, transthecal digital block

anesthetic, as demonstrated by improved proximal dorsal anesthesia with 2% lidocaine with betamethasone compared to 1% lidocaine with betamethasone.<sup>34</sup>

### 3.6 | Pain of injection

Of the studies reporting pain of injection, 12 studies used a visual analog scale<sup>9-14,16,17,20,21,26,34</sup> and 3 studies used a numeric rating scale.<sup>15,18,24</sup> After converting all pain scores to a 1–10 scale, our meta-analysis revealed an overall mean pain score of 3.3 (95% CI [2.9, 3.8]) and no significant difference in mean pain scores depending on digital nerve block approach (Figure 6A). Subanalysis of injections performed using buffered lidocaine found an average pain score of 2.1 (95% CI [1.3, 2.8]) (Figure 6B). We did not perform subanalyses on anesthetic type or temperature.

### 3.7 | Participant and clinician preference

Few studies reported the preferences of subjects or clinicians between single volar blocks versus 2-injection dorsal blocks. However, the studies reporting this information noted a preference for single-injection approaches. One study found that 22 of 27 subjects who had received both single- and double-injection blocks on opposite hands would prefer a single SIMPLE block over the traditional 2-injection dorsal block in the future.<sup>15</sup> Cannon et al noted that recruitment for their randomized control trial comparing the SCB to the TDB was difficult in part because clinicians had adopted the SCB as their typical practice because it was anecdotally effective.<sup>18</sup>

## 4 | DISCUSSION

Overall, our meta-analysis found no significant differences in the average TTA, DOA, or pain scores between different digital nerve block techniques. The average TTA for all digital nerve block techniques in our meta-analysis was 5 minutes, which can help emergency clinicians estimate the appropriate amount of time to wait for anesthesia onset before performing sensation testing and proceeding with the procedure. The average DOA for the 4 approaches to the digital nerve block performed with lidocaine ranged between 34 minutes and 237 minutes, or approximately 4 hours, which is useful for counseling patients regarding how long to expect numbness of their anesthetized digit. Pain of injection did not differ between digital nerve block approaches, although we did see that the average pain score for all techniques using buffered lidocaine was on average more than 1 point lower compared to the average pain score from both buffered and unbuffered anesthetic injections.

Our review of the literature reporting on the degree of anesthesia suggests that anesthesia of the dorsal surface of the digit is better achieved with dorsal approaches, whereas volar anesthesia of the digit is comparable between dorsal and volar approaches to the digital nerve block. Higher concentrations and higher volumes of anesthetic are also associated with an improved degree of anesthesia. The limited information available on participant and clinician preference for different digital nerve block techniques also suggest that a single-injection volar approach may be preferred over a dual-injection traditional dorsal block approach.

The results of our meta-analysis are similar to an evidence-based review by Harness in 2009.<sup>35</sup> Our results are also consistent with 1 study published after our meta-analysis was performed, which found

that the mean numerical rating scores for pain of injection using TDB versus SCB techniques were not significantly different<sup>5</sup>. Another study by Wheelock et al. that examined the pain of needlestick without injection of an anesthetic similarly found no significant difference in needlestick discomfort on the dorsal versus volar side of the digits.<sup>36</sup> Interestingly, this study found that 54% of volunteers preferred the dorsal over the volar needle stick, which is different from the preferences reported by the subjects in Williams and Lalonde's study.<sup>15,36</sup> It is important to note that the Wheelock et al. study performed only 1 dorsal needle stick on each volunteer, rather than the 2 needlesticks that would be required for a TDB.<sup>36</sup>

Several studies on digital nerve block technique outcomes could not be included in our meta-analysis because no SD or range was published. However, the data from these studies are consistent with our meta-analysis findings. Valvano and Leffler measured mean TTA and pain of injection scores with the TDB injection that were very similar to the findings of other studies in our meta-analysis.<sup>37</sup> Brutus et al found that the MTTB, SCB-A1-pulley, and MTTB-SCB were equally effective digital nerve block techniques for anesthesia to the volar surface of digits, with no significant difference in pain scores.<sup>31</sup> Cummings et al compared anesthesia at different zones of the digits for the TDB versus MTTB techniques.<sup>33</sup> They reported similar pain scores between the 2 techniques but found that the TTA of the TDB was 3.25 minutes faster than the MTTB, and the DOA was 4.63 minutes longer.<sup>33</sup> Although they found statistically significant differences in TTA and DOA between the 2 digital nerve block techniques, their reported measurements are within the range of the reported outcomes in the studies included in our meta-analysis, which cumulatively were not significantly different. Dehghani et al reported mean DOAs of 33.8 minutes for the TDB and 34.2 minutes for the TTB, which were within the lower range of DOAs reported for each of those techniques.<sup>32</sup> Our subanalysis found that buffered lidocaine is associated with decreased pain of injection, which is consistent with the results of studies that could not be included in our meta-analysis owing to differences in pain score evaluation method.<sup>38,39</sup> These studies found that alkalinization of lidocaine led to a statistically significant decrease in pain scores associated with traditional dorsal block.<sup>38,39</sup>

We did not specifically perform subanalyses on volume of injection, but the findings of Waitayawinyu et al are consistent with that of another study by Ballo et al, which used the SCB technique to compare 1 versus 2 ml of 2% lidocaine.<sup>26,40</sup> They found that the mean TTA of the volar surface with 1 ml (376 seconds, range 180–540 seconds) was significantly longer compared to the mean TTA with 2 ml (325 seconds, range 180–600 seconds) ( $P = 0.019$ ).<sup>40</sup> They also showed that complete volar anesthesia by pinprick testing was achieved in 17 out of 36 fingers injected with 2 ml lidocaine versus only 10 out of 36 fingers injected with 1 ml after 5 minutes, and 33 out of 36 fingers injected with 2 ml versus 26 out of 36 fingers injected with 1 ml after 10 minutes ( $P = 0.039$ ).<sup>40</sup> The data from these 2 studies suggest that using 2 ml or more of lidocaine for digital nerve blocks provides slightly faster TTA, longer DOA, and improved degree of anesthesia compared to blocks using 1 ml or less. Interestingly, in a pediatric population receiving

TTBs, Antevy et al recorded mean anesthetic volumes as low as 1.3 ml in the 0–2-year-olds and up to 2.6 ml in >10-year-olds with an overall success rate of 94%, suggesting that that amount of anesthetic needed for successful anesthesia may be correlated with the age of the patient or the size of the digit.<sup>3</sup>

The heterogeneity of the data limits our conclusions. Subjects in studies included healthy volunteers as well as patients with digital injuries or digital lesions requiring excision. Evaluation of pain and follow-up also varied from subjective reports and analgesic requirement to objective validated scales. Studies varied with respect to techniques, anesthetics used, definitions, and reporting of TTA and/or DOA (subject or observer report). A notable example of the variability in the data is the 2009 study by Sonohata et al that reported a TTA of 19.4 minutes using a deep MTTB technique with lidocaine mixed with iotralan contrast.<sup>25</sup> This much longer TTA is likely due to injection technique: 2 of the 10 deep MTTB injections failed to anesthetize the digit after 60 minutes, and the authors chose to count the TTA for those injections as 60 minutes in their calculation of the mean.<sup>25</sup> Although Sonohata et al. did not speculate as to why the deep MTTB might result in poorer anesthesia outcomes compared to other techniques, Low et al theorized that their similarly poor results with the TTB were likely due to intra-articular injection of anesthetic rather than injection into the flexor tendon sheath.<sup>23</sup> Low et al referenced their previous study that showed penetration of anesthetic into the metacarpophalangeal joint in 4 out of 20 TTB injections on cadaver hands.<sup>41</sup>

We attempted to limit our review to include randomized studies and cohort studies; however, participant measurements of anesthesia parameters and subjective reports of pain still proved limiting to generalizability of findings. In addition, this meta-analysis did not evaluate the ease of administering each technique, the type, temperature, volume of the anesthetic used, or the use of epinephrine with anesthetics for digital nerve blocks. A systematic review on the temperature of anesthetics found that warming of anesthetics before local injection results in less pain.<sup>42</sup> Epinephrine in anesthetics for digital nerve blocks has previously been reviewed and found to have insufficient evidence to recommend for or against its use in digital nerve blocks, though the same Cochrane review did not find any report of ischemia or necrosis with the use of epinephrine with lidocaine for digital nerve blocks.<sup>43</sup>

Clinical implications of our findings include optimizing time management in the ED for patients requiring a digital nerve block, counseling on the expected DOA, and preference toward using buffered local anesthetics rather than unbuffered to minimize pain of injection. Our meta-analysis also suggests that pain of injection does not differ between dorsal or volar approaches. Our review suggests that a volar single-injection approach to the digital nerve block may be preferable over a dorsal 2-injection approach as it reduces the number of needlesticks required. However, our review on degree of anesthesia suggests that a dorsal approach provides more reliable anesthesia to the proximal dorsal surface of the digit compared to volar approaches.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.



## AUTHOR CONTRIBUTIONS

T. Tausala Coleman-Satterfield, Ryan Kearney, and Eileen Joy Klein determined the objective for systematic review. Tiffany Y. Borbón, T. Tausala Coleman-Satterfield, Ryan Kearney, and Eileen Joy Klein completed the literature review. Tiffany Y. Borbón compiled the data from the studies included for meta-analysis. Pingping Qu provided statistical advice and analyzed the data. Tiffany Y. Borbón and T. Tausala Coleman-Satterfield drafted the manuscript, and all authors contributed substantially to its revision.

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**How to cite this article:** Borbón TY, Qu P, Coleman-Satterfield TT, Kearney R, Klein EJ. Digital nerve blocks: a systematic review and meta-analysis. *JACEP Open.* 2022;3:e12753. <https://doi.org/10.1002/emp2.12753>