

# Ultrasound compared with nerve stimulation guidance for peripheral nerve catheter placement: a meta-analysis of randomized controlled trials

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## Editor's key points

- An area of topical discussion is the role of ultrasound (US) in regional block.
- This systematic review and meta-analysis used Cochrane methodology to explore for possible differences between regional techniques.
- There was **little difference between US-guided regional blocks and nerve stimulator-placed blocks.**
- Further work is needed to **clarify what a 'successful' block is before doing larger scale studies.**

**Background.** The aim of this meta-analysis was to compare the efficacy and safety of ultrasound (US) vs nerve stimulation (NS) guidance for peripheral nerve catheter placement.

**Methods.** This meta-analysis was performed according to the PRISMA statement and the recommendations of the Cochrane Collaboration. For dichotomous outcomes relative risks [RRs; 95% confidence intervals (CIs)] were calculated, while for continuous outcomes, mean differences (MDs; 95% CI) were calculated. All statistical analyses were performed using the Revman® statistical software (Version 5.1).

**Results.** Fifteen randomized controlled trials including **977** patients satisfied the inclusion criteria. Peripheral nerve catheters placed under US guidance showed a **higher** RR of **1.14** (95% CI: 1.02–1.27;  $P=0.02$ ) for an overall **successful** block in comparison with NS. However, postoperative pain scales at movement (numeric rating scale: 0–10) were comparable between US- vs NS-guided peripheral nerve catheters 24 (MD: 0.08; 95% CI: –0.77 to 0.94;  $P=0.85$ ) and 48 (MD: 1.0; 95% CI: –0.3 to 2.3;  $P=0.13$ ) h after surgery. Patients receiving a US-guided peripheral nerve catheter had a **lower RR of 0.13** (95% CI: 0.04–0.38;  $P=0.0002$ ) for an accidental **vascular** puncture.

**Conclusions.** There is evidence that US-guided peripheral nerve catheters show a higher success rate and a lower risk for an accidental vascular puncture compared with NS guidance. However, **this difference resulted only in marginally lower postoperative pain scores at rest.** Nevertheless, these results were influenced by **heterogeneity** and should be **interpreted** with **caution.**

**Keywords:** acute pain, regional techniques; anaesthetic techniques, regional; regional anaesthesia

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The perioperative use of ultrasound (US) as the primary guiding technique for regional anaesthesia has significantly increased during the past two decades and might have replaced the former 'gold standard' nerve stimulation (NS).<sup>1–2</sup> Two recent meta-analyses demonstrated numerous advantages of US-guided peripheral nerve blocks in comparison with NS, including higher success rates, lower need of local anaesthetics, reduced performance, and onset time and also reduced complication rates.<sup>3–8</sup> However, as mentioned in a recent editorial by Ilfeld and colleagues,<sup>9</sup> data focusing specifically on US-compared with NS-guided peripheral nerve catheter placement are currently lacking in the literature.

Therefore, the aim of the present meta-analysis was to compare the success rates, performance times, postoperative pain outcomes, and rates of neurological complications of US- vs NS-guided peripheral nerve catheters for postoperative pain therapy.

## Methods

This systematic review of randomized controlled trials was performed according to the criteria of the PRISMA statement<sup>10</sup> and the current recommendations of the Cochrane Collaboration.

<sup>†</sup> Both authors contributed equally.

## Search strategy and study selection

A systematic search of the databases MEDLINE, CENTRAL, and EMBASE was performed by two authors (A.S./C.H.M.-F.) using free text words ('regional anaesthesia' or 'peripheral nerve catheter' or 'continuous nerve block' or 'electrical stimulation' or 'nerve stimulation' or 'ultrasound') combined with MeSH terms (peripheral nerve and ultrasonography) but limited to randomized controlled trials. There were no restrictions regarding publication language or publication year. The last search was in June 2012. Two reviewers (A.S./C.H.M.-F.) primarily reviewed titles and abstracts in order to exclude irrelevant studies. Any controversy at any stage was discussed with a third author (P.K.Z.).

## Inclusion criteria

We included all randomized controlled trials comparing the efficacy and safety of US vs NS guidance for peripheral nerve catheter placement. Additionally, we included all trials investigating a combination of both techniques vs one guiding technique alone (e.g. US combined with NS vs NS or US combined with NS vs US). All data irrespective of type of surgery (upper, lower extremity surgery) or utilized local anaesthetics were analysed.

## Data extraction and quality assessment

All relevant data were extracted from the original text or extrapolated from figures and tables by two authors (A.S./C.H.M.-F.) and entered on Excel sheets (Microsoft®, Redmond, WA, USA), which were specifically modified for this meta-analysis. Apart from the outcome parameters (see below), we extracted the type of surgery, the needle guidance technique used in the US group ('in plane' vs 'out of plane'), the use of final confirmation of catheter position in the US group, the type of anaesthesia (regional anaesthesia combined with general anaesthesia, regional anaesthesia alone), and the scheme of postoperative local anaesthetics (long-lasting or short-lasting local anaesthetics). If there were missing data, the reviewers tried to contact the corresponding authors of included trials to receive additional unpublished data.

Two reviewers (A.S./C.H.M.-F.) performed the critical evaluation of study quality; a modified Oxford scale published in several other meta-analyses was used.<sup>11</sup> This scale assessed the method of randomization (2 points), concealment of allocation (1 point), blinding (3 points), and description of dropouts (1 point).

## Definition of outcome parameters

The primary outcome was the overall number of patients with a perioperative successful peripheral nerve catheter placement ['success rate (overall)']. As already published in another meta-analysis comparing US vs NS for single peripheral nerve blocks all definitions (e.g. successful surgical block, successful sensory/motor block preoperative/postoperative, and successful needle/catheter placement within a defined time period) for successful peripheral nerve catheter placement were rated as equivalent.<sup>7</sup> As secondary outcomes, the

number of patients with a primary successful catheter placement (within a defined time period), pain scores [numeric rating scale (NRS): 0–10] during catheter placement ('procedure-related pain'), the time to perform (min), and post-operative pain scores at rest and movement (= 'worst pain') [in the postoperative care unit (PACU) (up to 2 h after operation), after 24 and 48 h] were calculated. If the included trials reported pain scores at more points in time, the highest scores within the time period would have been extracted. Finally, the number of patients with procedure-related complications [accidental vascular puncture, catheter-related infections, and neurological impairments (early/permanent)] were compared.

## Statistical analysis

We decided to analyse the outcome parameters separately according to the type of guiding technique, if more than two trials were included for this comparison (US vs NS; US combined with NS vs NS). The relative risk (RR), mean difference (MD), and their corresponding 95% confidence intervals (CIs) were calculated for the dichotomous and continuous outcome data using a fixed-effect model. Statistical heterogeneity was assessed with the  $I^2$ -test and assumed, if an  $I^2$ -value exceeding 30% was observed. If significant heterogeneity was detected, it was assumed that there was no single 'true' effect underlying the data, which was constant across different populations. In these cases, a random-effects model was used.<sup>12</sup> If continuous data were not reported as mean [standard deviation (SD)], the missing data were calculated as previously reported.<sup>13</sup> Significance was assumed if the 95% CI did not include the value 1.0. If relevant data heterogeneity was detected for the primary outcome, the following subgroups were separately analysed and compared: location of nerve catheter (interscalene, infraclavicular, femoral, and sciatic) and the use of final confirmation of catheter position in the US group ('yes' vs 'no'). Additionally, sensitivity analyses were planned to detect the influence of study quality (high-quality trials vs low-quality trials). All statistical analyses were performed with the Review Manager (RevMan®; Computer program; Version 5.1; Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2011).

## Results

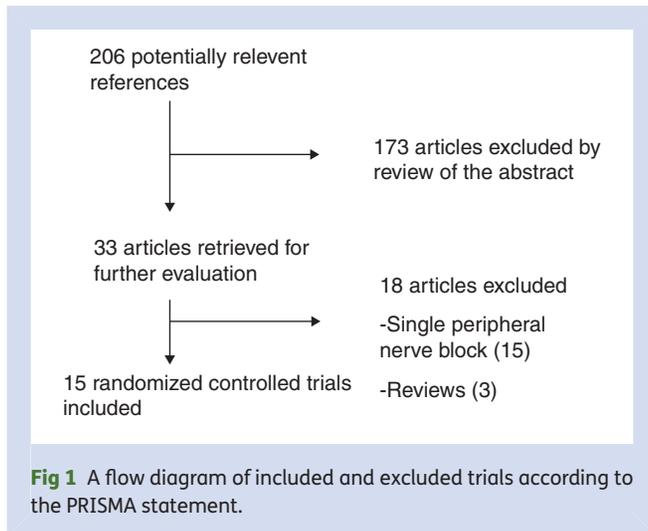
### Description of included and excluded studies

Our systematic search identified 206 trials, of which 191 studies were subsequently excluded (Fig. 1).

Fifteen studies (including 977 patients) satisfied the inclusion criteria and were finally included in the present meta-analysis<sup>14–28</sup> (Table 1). Within these 15 studies, nine studies compared US vs NS guidance.<sup>15–17 19 24–28</sup> The remaining studies investigated either US combined with NS vs NS<sup>14 18 22 23</sup> or US vs NS combined with US.<sup>20 21</sup> Four trials performed a distal-sciatic,<sup>15 23 25 27</sup> one performed a proximal-sciatic,<sup>17</sup> four performed a femoral,<sup>14 22 26</sup> four performed an interscalene,<sup>16 19 28</sup> and two performed an infraclavicular peripheral nerve catheter.<sup>18 25</sup>

The needle guidance techniques used within the US group favoured 'in plane' over 'out of plane' US technique.<sup>14 16–18 24–28</sup> Correct catheter placement in the US

group was verified by injecting air,<sup>24–27</sup> injecting local anaesthetics under visibility,<sup>14 18</sup> and using stimulation<sup>16 22</sup>—in five studies, an appropriate catheter localization was not ensured.<sup>15 17 19 23 28</sup> All studies with two exceptions<sup>14 15</sup> continued postoperative analgesia with ropivacaine; one study did not mention the type of local anaesthetic used for postoperative pain treatment.<sup>17</sup> While in 11 studies patients underwent surgery only under regional anaesthesia, six studies performed a general anaesthesia after nerve catheter placement.<sup>14 15 19 22</sup> Finally, seven trials applied a second regional anaesthetic block in addition to the investigated peripheral nerve catheter.<sup>14 15 17 19–21 23</sup>



### Critical appraisal of study quality

The included trials were all of a good quality (mean modified Oxford scale: 4.2). All trials used an adequate randomization method, but only nine trials<sup>14–20 22 23</sup> specified explicitly the method of allocation concealment (mainly via sealed envelopes); blinding of the patients and provider of intervention were not possible because of the completely different

**Table 1** Main characteristics of the included trials comparing US and NS for peripheral nerve catheter (PNC) placement. NSC, non-stimulating catheter; PCA, patient-controlled analgesia; GA+RA, combination of general and regional anaesthesia; IP, in plane; OOP, out of plane; +, yes; -, no

References	n (US)	n (control)	Nerve location	Used local anaesthetics	GA+RA	Additional nerve block/catheter	US needle guidance
Dhir and Ganapathy <sup>18</sup>	23 (US+NS)	22 (NS) 19 (NSC)	Infraclavicular	Mepivacaine 1.5%+ropivacaine 0.5%	–	–	IP
Danelli and colleagues <sup>17</sup>	30	30 (NS)	Proximal sciatic	Mepivacaine 1.5%	–	Femoral nerve block (US)	IP
Fredrickson and colleagues <sup>19</sup>	43	39 (NS)	Interscalene	Ropivacaine 0.5%+ropivacaine 0.2% PCA	+	Cervical plexus block	OOP
Fredrickson and colleagues <sup>20</sup>	41	40 (US+NS)	Interscalene	Ropivacaine 0.5%+ropivacaine 0.2% PCA	+	Cervical plexus block	OOP
Fredrickson and colleagues <sup>21</sup>	21	24 (US+NS)	Femoral	Ropivacaine 0.375/0.5%+ropivacaine 0.2/0.3% PCA	+	Distal-sciatic nerve block (US+NS)	OOP
Mariano and colleagues <sup>24</sup>	20	20 (NS)	Distal sciatic	Mepivacaine 1.5%+ropivacaine 0.2% PCA	–	–	IP
Mariano and colleagues <sup>25</sup>	20	20 (NS)	Infraclavicular	Mepivacaine 1.5%+ropivacaine 0.2% PCA	–	–	IP
Mariano and colleagues <sup>26</sup>	20	20 (NS)	Femoral	Mepivacaine 1.5%+ropivacaine 0.2% PCA	–	–	IP
Aveline and colleagues <sup>14</sup>	46 (US+NS)	46 (NS)	Femoral	Levobupivacaine 0.5%+levobupivacaine 0.125% PCA	+	Proximal-sciatic nerve block (US+NS)	IP
Mariano and colleagues <sup>27</sup>	40	40 (NS)	Distal sciatic	Mepivacaine 1.5%+ropivacaine 0.2% PCA	–	–	IP
Mariano and colleagues <sup>28</sup>	20	20 (NS)	Interscalene	Mepivacaine 1.5%+ropivacaine 0.2% PCA	–	–	IP
Bendtsen and colleagues <sup>15</sup>	50	48 (NS)	Distal sciatic	Ropivacaine 0.75%+bupivacaine 0.25% PCA	+	Distal saphenous nerve block	OOP
Li and colleagues <sup>22</sup>	60 (US+NS)	60 (NS)	Femoral	Lidocaine 1%+ropivacaine 0.2%	+	–	OOP
Danelli and colleagues <sup>16</sup>	25	25 (NS)	Interscalene	Ropivacaine 1%+ropivacaine 0.25% PCA	–	–	IP
Maalouf and colleagues <sup>23</sup>	24 (US+NS)	21 (NS)	Distal sciatic	Bupivacaine 0.5%+ropivacaine 0.2%	–	Combined spinal epidural	OOP

interventions (US vs NS). Nine trials<sup>14-17 19-23</sup> mentioned explicitly that the observers were blinded.<sup>14-17 19-23</sup>

**Primary and secondary outcome data of trials comparing US vs NS guidance for peripheral nerve catheters**

Nine randomized controlled trials including 530 patients ( $n_{US}=268$ ;  $n_{NS}=262$ ) investigated the comparison of US vs NS guidance for peripheral nerve catheter placement.<sup>15-17 19 24-28</sup>

**Number of patients with a successful peripheral nerve catheter placement [‘success rate (overall)’]**

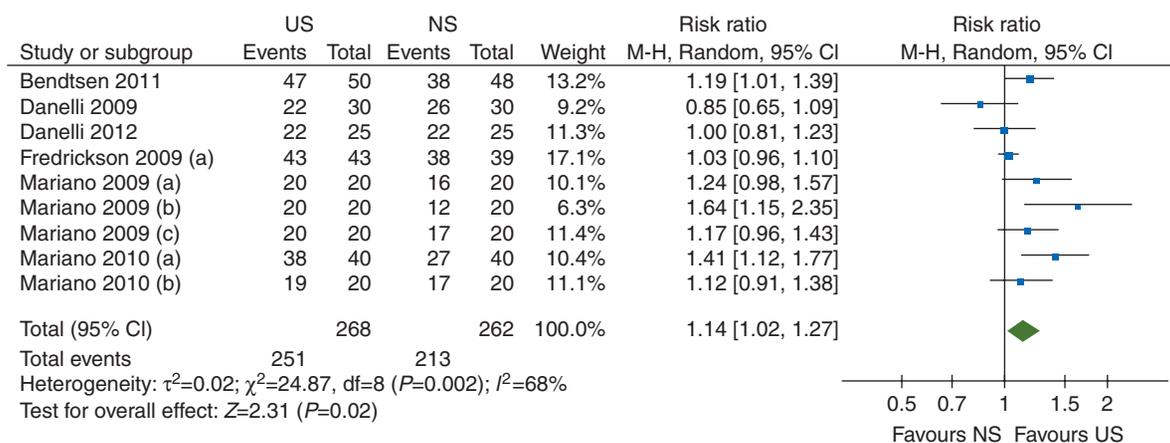
All included trials (530 patients) evaluated the number of patients with an overall successful peripheral nerve catheter for an effective intra- and postoperative analgesia. Definitions of a successful catheter placement varied between the included trials and are summarized in Supplementary Table S2.

Patients receiving a US-guided peripheral nerve catheter had a higher RR of 1.14 for a successful placement compared with the NS group (Fig. 2). The sensitivity analysis focusing on differences because of the study quality demonstrated a lower RR for a successful peripheral nerve catheter placement (RR: 1.04; 95% CI: 0.90–1.19;  $P=0.62$ ;  $I^2=62\%$ ) in the high-quality trials (modified Oxford scale  $>4$ )<sup>15 17 19</sup> compared with low-quality trials

(modified Oxford scale  $\leq 4$ ) (RR: 1.21; 95% CI: 1.07–1.38;  $P=0.003$ ;  $I^2=46\%$ ).<sup>24-28</sup> The subgroup analysis according to each block location demonstrated a significantly higher RR for a successful distal sciatic<sup>15 24 27</sup> or infraclavicular peripheral nerve catheter<sup>25</sup> compared with other anatomical locations (Table 2). An additional subgroup analysis focusing on the impact of the final confirmation of catheter position in the US group (‘yes’ vs ‘no’) showed a higher RR for a successful nerve catheter, if the catheter location was finally controlled in the US group<sup>24-27</sup> (RR: 1.35; 95% CI: 1.19–1.54;  $P<0.00001$ ;  $I^2=19\%$ ) compared with no final confirmation (RR: 1.05; 95% CI: 0.96–1.14;  $P=0.31$ ;  $I^2=31\%$ ).<sup>15-17 19 28</sup>

**Number of patients with a primary successful catheter placement (within a defined time period)**

There were six trials available<sup>19 24-28</sup>—five trials<sup>24-28</sup> used stimulation catheters as control—evaluating the number of patients with primary successful catheter placement within a defined time period (30 min for catheter placement/5 min for needle placement) (Supplementary Table S2). US-guided peripheral nerve catheter placement was associated with a higher RR of 1.18 compared with NS guidance (Supplementary Fig. S3).



**Fig 2** Meta-analysis of the number of patients with a successful peripheral nerve catheter after a US- vs NS-guided peripheral nerve catheter.<sup>15-17 19 24-28</sup>

**Table 2** Success rate (overall) of US- compared with NS-guided peripheral nerve catheters (PNCs) at different anatomical nerve locations

Nerve catheter location	References	RR	95% CI	P-value	$I^2$
Distal-sciatic PNC	15 24 27	1.25	1.12–1.41	0.0001	0%
Proximal-sciatic PNC	17	0.85	0.65–1.09	0.2	
Femoral PNC	26	1.17	0.96–1.43	0.13	
Interscalene PNC	16 19 20 28	1.04	0.96–1.13	0.35	0%
Infraclavicular PNC	25	1.64	1.15–2.35	0.007	

### Postoperative pain at rest and movement (PACU, 24, 48 h postoperative)

Eight trials reported postoperative pain scores at rest and the movement of patients treated with a US- or NS-guided peripheral nerve block. The pooled data analysis demonstrated only for pain at rest 24 h postoperative lower NRS (MD:  $-0.53$  U) in the US group (Supplementary Fig. S4). At all other points in time, there were no differences in pain at rest. Similar results were observed for postoperative pain at movement 24 (Fig. 3) and 48 h postoperative.

### Procedure-related pain/discomfort, time to perform (min)

Eight trials<sup>16 17 19 24-28</sup> were included focusing on procedure-related pain, while only seven studies<sup>16 17 19 24-28</sup> reported the time to perform catheter placement. US-guided peripheral nerve catheter caused less pain (NRS: 0–10) during placement (MD:  $-1.07$  U; 95% CI:  $-1.76$  to  $-0.39$ ;  $P=0.002$ ;  $I^2=78%$ ) and took less time (MD:  $-3.88$  min; 95% CI:  $-5.21$  to  $-2.56$ ;  $P<0.00001$ ;  $I^2=41%$ ) compared with NS guidance.

### Number of patients with catheter-related complications [accidental vascular puncture, catheter-related infections, and neurological impairments (early/permanent)]

All included trials reported patients with catheter-related complications. The most common complication during catheter placement was the accidental vascular puncture, whereas US guidance was associated with a lower RR of 0.13 (95% CI: 0.04–0.38;  $P=0.0002$ ;  $I^2=0%$ ). Only one trial<sup>15</sup> reported that there were no catheter-related infections in both groups. Temporary neurological complications were only noted in one<sup>19</sup> out of four trials<sup>15-17 19</sup> with an almost comparable RR of 0.91 (95% CI: 0.19–4.23;  $P=0.90$ ) for both guiding techniques. Permanent nerve injuries were not reported because of the short postoperative follow-up period.

### Primary and secondary outcome data of trials comparing US combined with NS vs NS guidance for peripheral nerve catheters

We included four trials including 302 patients ( $n_{US+NS}=153$ ;  $n_{NS}=149$ ), which compared the efficacy and safety of US combined with NS vs NS guidance for peripheral nerve catheter placement.<sup>14 18 22 23</sup>

### Number of patients with an overall successful peripheral nerve catheter placement [‘success rate (overall)’]

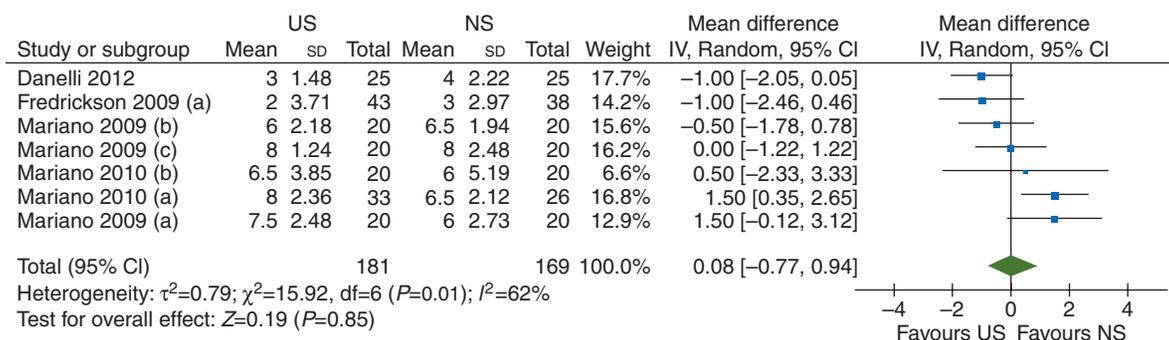
The number of patients with a successful peripheral nerve catheter placement was mentioned in all trials (302 patients). As already mentioned above definitions for block success varied and are summarized in Supplementary Table S2. The pooled data analysis revealed that peripheral nerve catheters, which were placed with US and NS, showed an almost comparable RR of 1.08 (95% CI: 0.97–1.21;  $P=0.17$ ,  $I^2=77%$ ) with NS-guided catheters (Fig. 4). Because of limited data no subgroup and sensitivity analyses were performed.

### Number of patients with a primary successful catheter placement (within a defined time period), time to perform (min), and procedure-related pain/discomfort

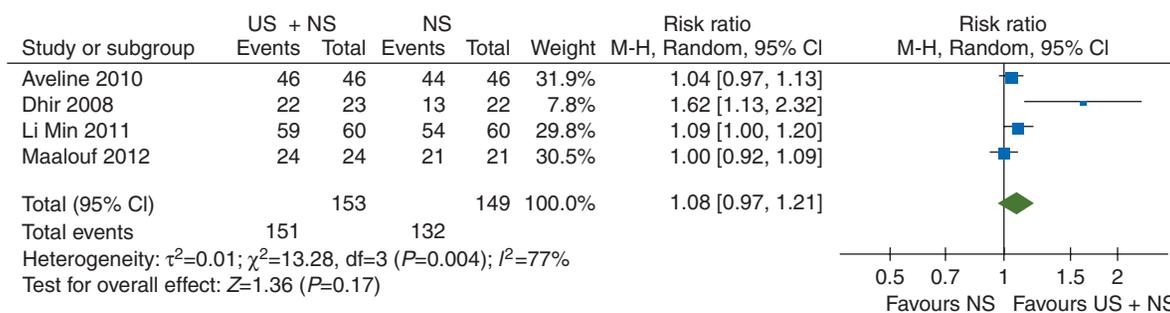
Because of limited study data no pooled analyses were performed for these outcomes.

### Postoperative pain at rest and movement (PACU, 24, 48 h postoperative)

Three trials<sup>14 22 23</sup> reported postoperative pain scores at rest and movement (PACU, 24, 48 h postoperative) in both groups. Patients treated with a US combined with NS-guided nerve catheter reported lower NRS at rest at all points in time (Supplementary Table S4). However, the pooled results for postoperative pain scores at movement were different between 24 and 48 h postoperative, while for pain at movement in the PACU no study data were available (Supplementary Table S4).



**Fig 3** Pooled data analysis of MDs of pain scores (NRS: 0–10) at movement 24 h postoperative in patients treated with a US- vs NS-guided peripheral nerve catheter.<sup>16 19 24-28</sup>



**Fig 4** Meta-analysis of the number of patients with a successful peripheral nerve catheter after a US combined with NS- vs NS alone guided peripheral nerve catheter.<sup>14 18 22 23</sup>

**Number of patients with catheter-related complications [accidental vascular puncture, catheter-related infections, and neurological impairments (early/permanent)]**

Patients with catheter-related complications were mentioned in three trials.<sup>14 18 22</sup> An accidental vascular puncture was the most common adverse event during catheter placement, whereas patients receiving a US combined with NS-guided nerve catheter suffered a lower RR of 0.2 (95% CI: 0.02 – 1.66;  $P=0.14$ ). After operation no patient had a catheter-related infection. Additionally, only one patient treated with a US combined with NS-guided femoral nerve catheter complained about short-lasting (5 days) paraesthesia in the saphenous nerve area.<sup>14</sup>

**Discussion**

This meta-analysis is based on the data of 15 included randomized controlled trials (977 patients) and compared the efficacy and safety of three different guiding techniques (including US, NS, or both) for peripheral nerve catheter placement: US ( $n=268$ ) vs NS ( $n=262$ ), US+NS ( $n=153$ ) vs NS ( $n=149$ ), and US ( $n=62$ ) vs NS+US ( $n=64$ ). US-guided peripheral nerve catheter placement showed a significantly higher overall success rate and a lower risk for an accidental vascular puncture than NS-guided catheters. However, postoperative pain scores at rest and movement were comparable after a US- or NS-guided peripheral nerve catheter placement.

**Efficacy of US guidance for peripheral nerve catheters**

There is currently clear evidence in the literature that continuous regional anaesthesia provides better postoperative analgesia and causes less nausea in comparison with systemic opioids after major extremity surgery (e.g. total knee replacement).<sup>29</sup> Additionally, US guidance is currently believed to be the ‘gold standard’ for single-shot regional anaesthesia,<sup>2</sup> but this evidence is currently lacking for peripheral nerve catheter placement. Our meta-analysis demonstrated a higher overall success rate, a higher RR for a primary successful peripheral nerve catheter placement within a defined time period, lower

procedure-related pain scores, and faster procedure times in US-guided peripheral nerve catheters compared with NS. An additional subgroup analysis revealed that trials, which investigated US vs NS for distal-sciatic nerve catheter placement, reported the highest overall success rates; these results were in accordance with other published meta-analyses focusing on single peripheral nerve blocks.<sup>7 8</sup> However, as mentioned above (Supplementary Table S2), definitions for block success used in this meta-analysis varied and a current standard description for blocking success is lacking at the moment.<sup>30</sup> Included trials reported more often the number of patients with primary failed catheter placements (no successful peripheral nerve catheter placement within a defined time period) rather than the number of patients with successful, perioperative analgesia—which might be clinically more relevant for the patients. Furthermore, many trials used a stimulation catheter in the NS group, which is more difficult to be accurately placed as demonstrated in this meta-analysis. Additionally, many included trials excluded patients with a primary catheter placement failure (no successful peripheral nerve catheter placement within a defined time period), which also might have influenced the outcomes. Therefore, the calculated overall success rate might be overestimated and should be interpreted with caution.

The current meta-analysis demonstrated the importance of the final confirmation of the correct catheter position in close proximity to the nerve. Trials, which confirmed the final position of the catheter tip with ultrasound, showed a moderate higher success rate than those not using any method for confirmation in the US group. The most common technique used by the trials in this meta-analysis was the injection of air.<sup>31</sup> However, air injection as a control for correct catheter placement has its limitations because of air induced artifacts and subsequently a reduced visibility of the catheter. We hypothesize that an injection of agitated local anaesthetics after catheter placement avoids artifacts, allows an adjustment of catheter location after placement—if necessary—and may even improve the success rate and postoperative pain scores of peripheral nerve catheters. This has already been shown in

a case report,<sup>32</sup> but has not been investigated in a randomized controlled trial yet.

We also analysed trials investigating the combination of US+NS vs NS and revealed that the overall success rate was almost comparable, but the postoperative pain scores tended to be lower in the US+NS group. Because of the lacking data, we could not analyse the combination of US+NS vs US, but the included trials<sup>20–21</sup> reported comparable success rates and postoperative pain scores for both techniques, but a longer time to perform, if US was used in combination with NS.

### Safety of US guidance for peripheral nerve catheters

Several large prospective trials demonstrated the low number of adverse events after peripheral nerve catheters.<sup>33–35</sup> The published meta-analysis comparing US vs NS for single peripheral nerve block suggested a lower RR for vascular puncture, but a comparable RR for neurological complications after US guidance.<sup>7</sup> Our meta-analysis confirmed these results for peripheral nerve catheter placement. Regarding the lower RR for accidental vascular punctures US offers the possibility to visualize the surrounding blood vessels and needle movements that the risk for an inadvertent ‘bloody’ puncture was significantly lower. The overall risk for catheter-related nerve damages is known to be difficult to assess, but the currently pooled incidence for a permanent nerve injury is believed to be 0.07%.<sup>3–36</sup> Patients with temporal neurological complications were only reported in two trials after interscalene catheter placement<sup>19–20</sup>—with six patients after a US+NS-guided peripheral nerve catheter<sup>20</sup> and three patients after NS guidance.<sup>19</sup> The latter finding shows that the anatomical nerve location might even more contribute to the risk for an accidental nerve damage than the guiding technique; the interscalene brachial plexus might have a higher risk for nerve damage because of the lower myelination of the nerves compared with other peripheral nerves.<sup>37</sup>

### Implications for practice

Although US and NS are two different guiding techniques for peripheral nerve catheter placement and both techniques have their advantages and limitations, several experts in regional anaesthesia asked whether it is ‘time to ask the question’ regarding further NS use in the future.<sup>38</sup> This meta-analysis demonstrated that the use of US might be the favourable guiding technique for the block of superficial peripheral nerves (e.g. distal-sciatic nerve). However, it might be more difficult to block deeper nerve structures (e.g. proximal-sciatic nerve) with US guidance alone and may necessitate in some cases the addition of NS confirmation.<sup>15–17 19 28</sup> Furthermore, in most trials included in this meta-analysis regional anaesthesia, experts performed the peripheral nerve catheter placements. Although several trials demonstrated the increased learning curve for US-guided regional anaesthesia in trainees,<sup>39 40</sup> in the beginning of US-guided regional analgesia a combination of US and NS could be a valuable option for an accurate placement of peripheral nerve catheters.<sup>41</sup> Therefore, from our point of view, US represents the ‘gold standard’ for continuous regional anaesthesia, but under special conditions (e.g. difficult anatomy,

deep nerve structure, and regional anaesthesia education) NS is still a valuable technique to provide additional information for a correct peripheral nerve catheter placement.

### Limitations

The result of each meta-analysis is limited by the heterogeneity of included trials. As mentioned above, definitions of block success were different in the included trials and a recently published review concluded that a consistent standard for the definition of block success is currently lacking in the literature.<sup>30</sup> Therefore, this inconsistent success definition (Supplementary Table S2) might have influenced the primary outcome, although our calculated RR for a successful peripheral nerve catheter was similar to a recent publication investigating single-shot regional anaesthesia.<sup>7</sup>

Additionally, as has been already mentioned above, many trials excluded the patients with primary catheter failure from further analysis. We tried to get insight into this influence by analysing the outcome ‘number of patients with primary successful catheter placement (within a defined time period)’. Although generally the number of patients excluded because of this reason was reasonable low, it might have influenced the other outcomes and the results should be interpreted with caution; therefore, future trials focusing on this issue should be performed on an intention to treat basis. As already mentioned in an editorial,<sup>42</sup> many studies comparing US vs NS as guiding technique for regional anaesthesia applied different amounts of local anaesthetics during initial peripheral nerve catheter placement and postoperative pain treatment, which might have also increased the heterogeneity of the primary and secondary outcome data. Additionally, different US needle techniques (‘in plane’ and ‘out of plane’) were used, but a standard for peripheral nerve catheter placement is currently lacking in the literature. Because of the different interventions (US vs NS) blinding of the provider of peripheral nerve catheter placements and the patient were not possible, which might also lead to a higher impact of a potential bias. Furthermore, eight included trials<sup>19–21 24–28</sup> were only performed by two primary investigators, which might contribute to a multiple publication bias.

### Conclusion

There is ample evidence that US-guided peripheral nerve catheter placement is associated with a higher success rate and a lower risk for accidental vascular puncture compared with NS guidance. However, these advantages in catheter placement resulted only in a minor reduction of postoperative pain scores at rest. Nevertheless, the fact that the final position of peripheral nerve catheter was rarely confirmed in the US group, might have influenced these results. Furthermore, the latter findings were influenced by significant heterogeneity and should be therefore interpreted with caution.

### Authors’ contributions

A.S.: study design, literature search, data extraction, data analysis, writing the first draft of the paper, revising the article, and

final approval. C.H.M.-F.: literature search, data extraction, data analysis, writing the first draft of the paper, and final approval. P.K.Z.: study design, data analysis, writing the first draft of the paper, revising the article, and final approval. E.M.P.-Z.: study design, data analysis, revising the article, and final approval.

## Supplementary material

Supplementary material is available at *British Journal of Anaesthesia* online.

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## Declaration of interest

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## References

- Marhofer P, Harrop-Griffiths W, Kettner SC, Kirchmair L. Fifteen years of ultrasound guidance in regional anaesthesia: part 1. *Br J Anaesth* 2010; **104**: 538–46
- Marhofer P, Willschke H, Kettner S. Current concepts and future trends in ultrasound-guided regional anaesthesia. *Curr Opin Anaesthesiol* 2010; **23**: 632–6
- Barrington MJ, Watts SA, Gledhill SR, et al. Preliminary results of the Australasian Regional Anaesthesia Collaboration: a prospective audit of more than 7000 peripheral nerve and plexus blocks for neurologic and other complications. *Reg Anesth Pain Med* 2009; **34**: 534–41
- Ilfeld BM, Morey TE, Enneking FK. Continuous infraclavicular brachial plexus block for postoperative pain control at home: a randomized, double-blinded, placebo-controlled study. *Anesthesiology* 2002; **96**: 1297–304
- Neal JM. Ultrasound-guided regional anesthesia and patient safety: An evidence-based analysis. *Reg Anesth Pain Med* 2010; **35**: S59–67
- Salinas FV. Location, location, location: continuous peripheral nerve blocks and stimulating catheters. *Reg Anesth Pain Med* 2003; **28**: 79–82
- Abrahams MS, Aziz MF, Fu RF, Horn JL. Ultrasound guidance compared with electrical neurostimulation for peripheral nerve block: a systematic review and meta-analysis of randomized controlled trials. *Br J Anaesth* 2009; **102**: 408–17
- Gelfand HJ, Ouanes JP, Lesley MR, et al. Analgesic efficacy of ultrasound-guided regional anesthesia: a meta-analysis. *J Clin Anesth* 2011; **23**: 90–6
- Ilfeld B, Fredrickson M, Mariano E. Ultrasound-guided perineural catheter insertion: three approaches but few illuminating data. *Reg Anesth Pain Med* 2010; **35**: 123–6
- Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *Br Med J* 2009; **339**: b2700
- Elia N, Tramer MR. Ketamine and postoperative pain—a quantitative systematic review of randomised trials. *Pain* 2005; **113**: 61–70
- Schnabel A, Reichl SU, Kranke P, Pogatzki-Zahn EM, Zahn PK. Efficacy and safety of paravertebral blocks in breast surgery: a meta-analysis of randomized controlled trials. *Br J Anaesth* 2010; **105**: 842–52
- Popping DM, Elia N, Marret E, Wenk M, Tramer MR. Clonidine as an adjuvant to local anesthetics for peripheral nerve and plexus blocks: a meta-analysis of randomized trials. *Anesthesiology* 2009; **111**: 406–15
- Aveline C, Le Roux A, Le Hetet H, Vautier P, Cognet F, Bonnet F. Post-operative efficacies of femoral nerve catheters sited using ultrasound combined with neurostimulation compared with neurostimulation alone for total knee arthroplasty. *Eur J Anaesth* 2010; **27**: 978–84
- Bendtsen TF, Nielsen TD, Rohde CV, Kibak K, Linde F. Ultrasound guidance improves a continuous popliteal sciatic nerve block when compared with nerve stimulation. *Reg Anesth Pain Med* 2011; **36**: 181–4
- Danelli G, Bonarelli S, Tognu A, et al. Prospective randomized comparison of ultrasound-guided and neurostimulation techniques for continuous interscalene brachial plexus block in patients undergoing coracoacromial ligament repair. *Br J Anaesth* 2012; **108**: 1006–10
- Danelli G, Ghisi D, Fanelli A, et al. The effects of ultrasound guidance and neurostimulation on the minimum effective anesthetic volume of mepivacaine 1.5% required to block the sciatic nerve using the subgluteal approach. *Anesth Analg* 2009; **109**: 1674–8
- Dhir S, Ganapathy S. Comparative evaluation of ultrasound-guided continuous infraclavicular brachial plexus block with stimulating catheter and traditional technique: a prospective-randomized trial. *Acta Anaesthesiol Scand* 2008; **52**: 1158–66
- Fredrickson MJ, Ball CM, Dalgleish AJ. A prospective randomized comparison of ultrasound guidance versus neurostimulation for interscalene catheter placement. *Reg Anesth Pain Med* 2009; **34**: 590–4
- Fredrickson MJ, Ball CM, Dalgleish AJ, Stewart AW, Short TG. A prospective randomized comparison of ultrasound and neurostimulation as needle end points for interscalene catheter placement. *Anesth Analg* 2009; **108**: 1695–700
- Fredrickson MJ, Danesh-Clough TK. Ambulatory continuous femoral analgesia for major knee surgery: a randomised study of ultrasound-guided femoral catheter placement. *Anaesth Intensive Care* 2009; **37**: 758–66
- Li M, Xu T, Han WY, Wang XD, Jia DL, Guo XY. Use of ultrasound to facilitate femoral nerve block with stimulating catheter. *Chin Med J* 2011; **124**: 519–24
- Maalouf D, Liu SS, Movahedi R, et al. Nerve stimulator versus ultrasound guidance for placement of popliteal catheters for foot and ankle surgery. *J Clin Anesth* 2012; **24**: 44–50
- Mariano ER, Cheng GS, Choy LP, et al. Electrical stimulation versus ultrasound guidance for popliteal-sciatic perineural catheter insertion: a randomized controlled trial. *Reg Anesth Pain Med* 2009; **34**: 480–5
- Mariano ER, Loland VJ, Bellars RH, et al. Ultrasound guidance versus electrical stimulation for infraclavicular brachial plexus perineural catheter insertion. *J Ultrasound Med* 2009; **28**: 1211–8
- Mariano ER, Loland VJ, Sandhu NS, et al. Ultrasound guidance versus electrical stimulation for femoral perineural catheter insertion. *J Ultrasound Med* 2009; **28**: 1453–60
- Mariano ER, Loland VJ, Sandhu NS, et al. Comparative efficacy of ultrasound-guided and stimulating popliteal-sciatic perineural catheters for postoperative analgesia. *Can J Anaesth* 2010; **57**: 919–26

- 28 Mariano ER, Loland VJ, Sandhu NS, et al. A trainee-based randomized comparison of stimulating interscalene perineural catheters with a new technique using ultrasound guidance alone. *J Ultrasound Med* 2010; **29**: 329–36
- 29 Paul JE, Arya A, Hurlburt L, et al. Femoral nerve block improves analgesia outcomes after total knee arthroplasty: a meta-analysis of randomized controlled trials. *Anesthesiology* 2010; **113**: 1144–62
- 30 Abdallah FW, Brull R. The definition of block 'success' in the contemporary literature: are we speaking the same language? *Reg Anesth Pain Med* 2012; **37**: 545–53
- 31 Sandhu NS, Capan LM. Ultrasound-guided infraclavicular brachial plexus block. *Br J Anaesth* 2002; **89**: 254–9
- 32 Swenson JD, Davis JJ, DeCou JA. A novel approach for assessing catheter position after ultrasound-guided placement of continuous interscalene block. *Anesth Analg* 2008; **106**: 1015–6, table of contents
- 33 Wiegel M, Gottschaldt U, Hennebach R, Hirschberg T, Reske A. Complications and adverse effects associated with continuous peripheral nerve blocks in orthopedic patients. *Anesth Analg* 2007; **104**: 1578–82, table of contents
- 34 Compere V, Rey N, Baert O, et al. Major complications after 400 continuous popliteal sciatic nerve blocks for post-operative analgesia. *Acta Anaesthesiol Scand* 2009; **53**: 339–45
- 35 Capdevila X, Pirat P, Bringuier S, et al. Continuous peripheral nerve blocks in hospital wards after orthopedic surgery: a multicenter prospective analysis of the quality of postoperative analgesia and complications in 1,416 patients. *Anesthesiology* 2005; **103**: 1035–45
- 36 Ilfeld BM. Continuous peripheral nerve blocks: a review of the published evidence. *Anesth Analg* 2011; **113**: 904–25
- 37 Popping DM, Zahn PK, Van Aken HK, Dasch B, Boche R, Pogatzki-Zahn EM. Effectiveness and safety of postoperative pain management: a survey of 18 925 consecutive patients between 1998 and 2006 (2nd revision): a database analysis of prospectively raised data. *Br J Anaesth* 2008; **101**: 832–40
- 38 Allan A, Bedforth N, Nicholls B, Denny N. Comparing ultrasound and nerve stimulation: time to ask the question? *Anaesthesia* 2011; **66**: 222–3
- 39 Luyet C, Schupfer G, Wipfli M, Greif R, Luginbuhl M, Eichenberger U. Different learning curves for axillary brachial plexus block: ultrasound guidance versus nerve stimulation. *Anesthesiol Res Pract* 2010; **2010**: 309–462
- 40 Sites BD, Gallagher JD, Cravero J, Lundberg J, Blike G. The learning curve associated with a simulated ultrasound-guided interventional task by inexperienced anesthesia residents. *Reg Anesth Pain Med* 2004; **29**: 544–8
- 41 Orebaugh SL, Williams BA, Kentor ML. Ultrasound guidance with nerve stimulation reduces the time necessary for resident peripheral nerve blockade. *Reg Anesth Pain Med* 2007; **32**: 448–54
- 42 Torrillo TM, Rosenblatt MA. Meta-analyses of ultrasound-guided versus traditional peripheral nerve block techniques – are we comparing apples and oranges? *J Clin Anesth* 2011; **23**: 87–9

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