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Best Practice & Research Clinical Anaesthesiology

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Peripheral nerve catheters: A critical review of the efficacy



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Keywords:

anesthetics
local
nerve block
pain
postoperative
infusion
analgesia

Continuous peripheral nerve blocks are commonly used for post-operative analgesia after surgery. However, catheter failure may occur due to either primary (incorrect insertion) or secondary reasons (displacement, obstruction, disconnection). Catheter failure results in unanticipated pain, need for opioid use, and risk of readmission or delay in hospital discharge. This review aimed to assess definition and frequency of catheter failure, and discuss the alternatives to prolong duration of single-shot nerve blocks. A literature search was performed on peripheral catheters reporting failure as the main outcome measure. Thirty-three studies met the selection criteria, comprising 2711 catheters. Literature review suggests that peripheral nerve catheters have clinically significant failure rate when the assessment is performed using an objective (imaging) method. Subjective methods of assessment (without imaging) may underestimate the incidence of catheter failure.

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Introduction

Single shot (sPNB) or continuous (cPNB) peripheral nerve blocks play an important role in post-operative pain management [1–6]. The widespread use of point of care ultrasound in the practice of regional anesthesia has expanded the use of interventional regional analgesia, and improved success rate of peripheral nerve blocks [7–15].

The cPNB techniques require both a successful insertion of the needle and a sustained position of the catheter-tip adjacent to the targeted neural structures to ensure delivery of local anesthetics in the therapeutic location for several days [16]. Catheters have been used to prolong the duration of peripheral nerve blocks when moderate to severe postoperative pain is expected to last more than 24 h [17,18]. This implies that cPNB have an advantage compared to sPNB and the use of adjuvants (e.g., dexamethasone) where the duration of analgesia is close to 24 h [19]. However, the use of catheters require an additional degree of expertise and is associated with decreased time-efficiency, increased risk for complications, and an additional expense of the equipment, pharmacology, and management of cPNB [20,21].

The purpose of this review is to define catheter failure, and methods of evaluation; assess the failure rate of cPNB, the evidence indicating whether cPNB are superior to single injection of local anesthetics with adjuvants, and if there is evidence indicating that cPNB may become obsolete by the introduction of liposomal bupivacaine, electrical peripheral nerve stimulation, radio-frequency and cryo-ablation.

Definitions

Catheter failure can be classified as primary or secondary. Primary failure is defined as a catheter misplacement during the initial ultrasound-guided insertion. The malpositioned catheter tip leads to the inaccurate, non-perineural spread of injectate [22,23].

A secondary failure is defined as the failure of a cPNB to provide analgesia *after* a period of effective analgesia [20]. Secondary failure can result from displacement of the catheter, leakage, disconnection or infusion pump malfunction. Both primary and secondary failure leads to unanticipated breakthrough pain [24–27]. The overall failure rate of cPNB can be defined as the sum of the primary and secondary failure rates.

Methods to assess the correct location of the catheter tip can be divided into objective and subjective methods. The use of ultrasound, for example, is an objective method to verify catheter location, while subjective markers for failure can be patient satisfaction, pain or cumulated opioid consumption, regardless of whether the data are obtained prospectively or retrospectively, typically by telephone interview, questionnaires or by review of the patient's medical records.

Methodology

A literature search was performed on November 22, 2018, using the electronic databases PubMed, EMBASE-Medline and Cochrane Library, with a set of keywords ([appendix A](#)). The list of references in the collected studies was screened manually for proxy data relevant for the assessment of the outcome variable “nerve catheter failure”: 1) Peripheral nerve catheters inserted in humans or cadavers or patients for upper or lower limb surgery, 2) Publications in English language, 3) Randomized controlled trials (RCT), controlled clinical trials, reviews, clinical trials or observational studies, 4) Catheters inserted under ultrasound guidance, 5) Report of the transducer orientation and catheter insertion technique 6) Report on duration and method of follow-up, 7) Presence of definition and report of primary and secondary cPNB failure or availability of the data allowing assessment of frequency of failure.

The literature search returned 456 studies in the search string. Of these, 371 articles were removed due to 1) written in a non-English language (87), 2) being meta-analysis, case-reports or conference abstracts (138), 3) being non-human studies (24), and 4) not concerning regional anesthesia or cPNB (122). Additional 52 articles were excluded due to the lack of information on cPNB failure (29), not clearly stated methods (6) or non-use of ultrasound-guidance (17). The remaining 33 studies included a total of 2711 peripheral nerve catheters as summarized in the PRISMA flow diagram ([Fig. 1](#), and [Table 1](#)).

These studies underwent additional critical review for the type of surgery, the number of catheters, anatomical location, insertion technique, failure method of assessment, and frequencies of primary and secondary catheter failures.

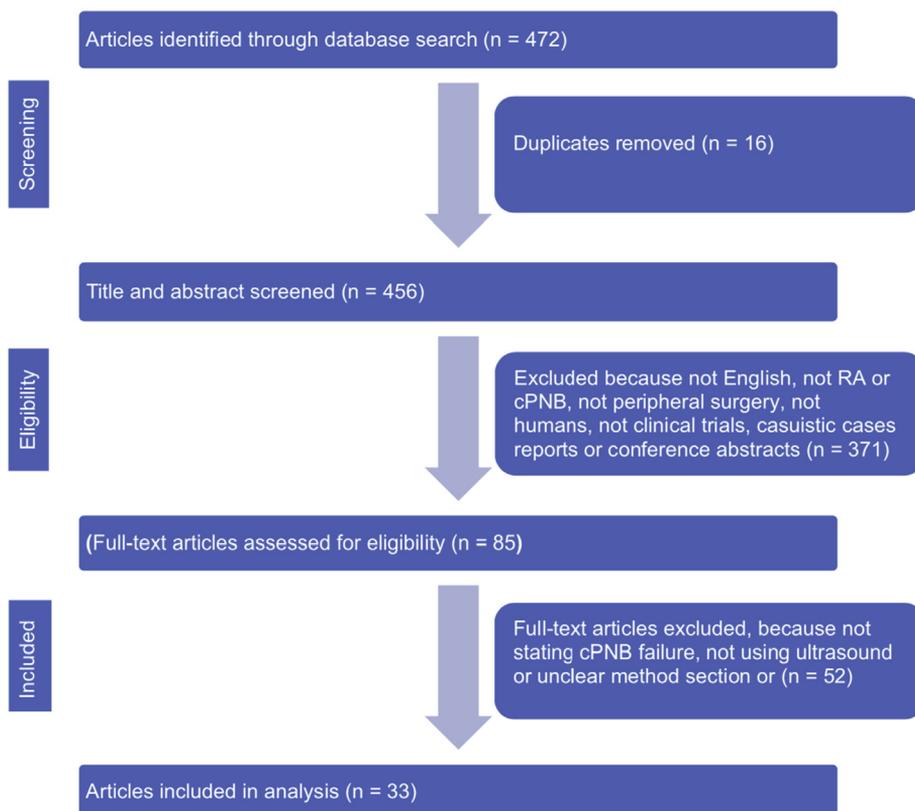


Fig. 1. PRISMA flow diagram of included studies on secondary nerve catheter failure rates. RA, regional anesthesia; cPNB, continuous peripheral nerve block.

Failure of cPNB

Frequencies of either primary or secondary failure of cPNB were assessed as the primary outcome in 3 studies [24–26], while the remaining studies reported or treated them as secondary outcomes. The reported secondary failure ranged from 0 to 50 percent [15–57]. As an example, 21% [95%CI: 6–36] of saphenous or so-called adductor canal catheters failed after a follow-up of 39 h [95%CI: 15–62]. As many as 18% [95%CI: 12–24] of catheters for upper limb surgery failed after 17 h [95%CI: 8–26]. Sciatic catheters failed in 16% [95%CI: 9–23] of patients after 35 h of insertion [CI95%: 21–50]. Femoral nerve catheters failed in 10% [95%CI: 4–17] and interscalene catheters in 11% [95%CI: 5–16] after 35 [CI95%: 13–57], and 39 h [CI95%: 21–57] respectively. Fixation of the catheter to the skin with glue or plastering did not appear to decrease secondary cPNB failure rate, as evaluated by opioid consumption [24,30]. However, the possibility of assessment bias, catheter insertion techniques, anatomical locations, variations in equipment and different infusion regimens made comparison difficult.

Primary cPNB failure

A key point of evaluating primary cPNB failure is whether the initial bolus of local anesthetic is injected via the needle [20,40,48,51,58] or via the catheter [24,26,34,35,54]. If a bolus is injected via the needle and not via the catheter, catheter failure cannot be reliably assessed due to the analgesic effect of the initial injection through the needle. This is because ropivacaine can result in analgesia of 10–15 h

Table 1

Included trials describing secondary catheter failure due to the displacement of ultrasound-guided peripheral nerve catheters. The trials are listed according to the anatomical region. Studies marked with *red* evaluated catheter failure by objective methods. Studies marked with *blue* evaluated catheter failure by subjective methods.

Study	N	Design	Insertion	P success	% Failure	Evaluated	Follow up time
Interscalene							
Auyong DB 2017	32	RCT-B	SAX-IP ^{Cyano}	Y	9	US, NST	2 nd POD
	34		SAX-IP ^{L5KAF}		35	SENS	
Marhofer D 2013	20	Case Series	SAX-OOP	Y	5	US	5 hours
Ahsan ZS 2014	16	Review	NS	NS	19	T, Q	1 st POD
Antonakakis JG 2009	16	Case series	SAX-IP	Y	0	VIS	4 th POD
Swenson JD 2006	190	Review	SAX-OOP	Y	7	T	3 rd POD
Fredrickson MJ 2008	300	Cohort	SAX-IP	Y	4	T, P	1 st POD
Mariano ER 2009	30	Cohort	SAX-IP	Y	10	VIS, P	Hours
Schwenk ES 2015	82	RCT	SAX-IP	N	11	VIS, P	2 nd POD
			SAX-OOP				
Shin HJ 2011	42	Cohort	SAX-IP	Y	8	VIS, P	2 nd POD
Mariano ER 2011	20	Review	NS	Y	10	C	1 st POD
Bryan NA 2007	144	Review	SAX-OOP	N	9	T	2 nd POD
Hamdani M 2014	90	RCT	SAX-OOP	Y	24	US, C, PP	2 nd POD
Upper limb							
Dhir S 2008	30	RCT	SAX-IP	Y	IC: 14	US NST	Hours
Dhir S 2008	23	RCT	SAX-IP	Y	IC: 22	US NST	Hours
						SENS	
Ahsan ZS 2014	191	Review	NS	NS	IC: 19 SC: 26	T, Q	1 st POD
Harrison TK 2015	36	RCT	SAX-IP	Y	IC: 6 SC: 17	P, VAS	1 st POD
Heil JW 2010	10	Cohort	SAX-IP	N	SC: 30	T	1 st POD
Mariano ER 2011	20	Review	NS	N	10	C	1 st POD
Femoral							
Marhofer D 2013	20	Case series	SAX-IP	Y	25	US	5 hours
Wang AZ 2010	25	RCT	SAX-IP	Y	0	US	2 nd POD
	25		SAX-OOP		12		
Mariano ER 2011	20	Review	NS	Y	10	C	1 st POD
Aveline C 2010	46	RCT-B	SAX-IP	Y	2	P	2 nd POD
Jäger P 2013	27	RCT-B	SAX-IP	Y	8	VIS	1 st POD
Kim HY 2016	50	RCT-B	SAX-IP	Y	4	NS	30 min
Seo SS 2017	30	Cohort	SAX-IP	NS	20	VIS	3 rd POD
Swenson JD 2006	206	Review	SAX-IP	Y	4	T	3 rd POD

(continued on next page)

and bupivacaine with or without dexamethasone up to 24–30 h [19]. In two studies, high volumes of local anesthetics were injected prior to catheter insertion. In the first study, 40 mL of mepivacaine 1.5% with epinephrine 2.5 mcg/mL was injected via the needle before insertion of popliteal sciatic nerve catheters prior to minor ambulatory foot surgery [42]. The morning after surgery, patients were contacted by telephone and they reported low pain scores between NRS 2 and 2.5 and a high degree of numbness. However, evaluation of nerve catheters by telephone on the first day after minor surgery combined with a large initial volume of mepivacaine injected via the needle weakens the internal validity of the assessment of catheter failure.

The second study compared out-of-plane vs. in-plane interscalene catheters for postoperative analgesia following open shoulder surgery [50]. Assessment of primary cPNB failure was compromised by an injection of 30 mL of ropivacaine 0.5% before catheter insertion. Although the follow-up period in this study was up to 48 h, catheter failure rates were evaluated after surgery in the PACU and again at 24 h after surgery by VAS, morphine consumption, catheter boluses, and displacement.

Table 1 (continued)

Femoral Triangle							
Jordahn ZM 2018	12	RCT-B	SAX-IP	Y	17	US SENS	Hours
	12		LAX-IP/OOP	Y	50		
Fisker AK 2015	50	RCT-B	SAX-IP	NS	6	P, M	2 nd POD
Jæger P 2013	24	RCT-B	SAX-IP	Y	8	VIS	1 st POD
Seo SS 2017	30	Cohort	SAX-IP	NS	37	VIS	3 rd POD
Andersen HL 2013	40	RCT-B	SAX-IP	Y	8	VIS	2 nd POD
Sciatic							
Hauritz RW 2016	20	RCT-B	SAX-IP	Y	40	MRI	48 hrs
	20		SAX-OOP		10		
Lyngeraa TS 2017	16	RCT-B	SAX-IP	Y	27	US	Hours
Mariano ER 2011	60	Review	SAX-IP	Y	10	C	24 hrs.
Bendtsen TF 2011	50	RCT	SAX-IP	Y	6	P, SENS	48 hrs
Ding DY 2015	23	RCT	NS	NS	35	VIS, T	Hours
Saporito A 2014	120	Cohort	SAX-IP	NS	11	T	3 rd POD
Swenson JD 2006	224	Review	SAX-IP	Y	2	T	3 rd POD
Fisker AK 2015	50	RCT-B	SAX-IP	NS	4	P, M	2 nd POD
Ilfeld B 2011	100	RCT	SAX-IP	NS	6	T	1 st POD
Kim TE 2014	22	RCT	LAX-IP	Y	23	T, P, C	1 st POD
	23		SAX-IP	Y	30		
Mariano ER 2010	40	RCT	SAX-IP	NS	6	C	1 st POD

RCT, Randomized Controlled Trial; B, blinded study; P Success: Proper assessment of primary placement of the catheter, e.g. by assessing sensory anesthesia after administering the first local anesthetic bolus via the catheter (Y, yes; N, no; NS, not specified). POD, post-operative day; SAX, short axis; IP, in-plane; OOP, out-of-plane; LAX, long axis; US, ultrasound; SENS, test of sensibility; NST, nerve stimulation; VIS, visual inspection of catheter site for obvious failure; MRI, magnetic resonance imaging; P, pain; VAS, visual analog scale; M, morphine; T, telephone interview; Q, questionnaire; C, chart review; Cyano, 2-Octyl Cyanoacrylate, topical skin adhesive; LSKAF, liquid skin adhesive fluid.

Assessment of primary cPNB failure is difficult if catheter insertion is performed under general, spinal anesthesia or deep sedation [59]. In one study, saphenous and femoral nerve catheters were inserted postoperatively while the patients were still under spinal anesthesia. An 8% failure rate was observed the day after surgery [43]. In another study, the first bolus of local anesthetic was delivered via the catheter, but most catheters were inserted in patients during general anesthesia so the primary catheter success rate also could not be determined. This study reported the secondary failure rate of 12 out of 300 catheters (4%) based on follow-up telephone interviews [17]. However, 23 catheters were replaced in the PACU after surgery due to primary failure; therefore the total failure rate was 11%. In addition, there could have been patients in whom catheters may not have been placed in the therapeutic position, but because they did not have significant post-surgical pain, the failure rate could have been higher, yet not possible to accurately estimate [60–62].

Therefore, underestimation of cPNB failure rate could occur if local infiltration analgesia is performed by the surgeon [15,31], insertion of catheters is done under spinal or general anesthesia [28,43,63], or if correct catheter placement is not verified by injecting the first bolus of local anesthetic via the catheter [33,36,64].

Secondary cPNB failure

A. Subjective assessment

Out of the 33 included studies about ultrasound-guided cPNB failure, 24 assessed secondary catheter failure by telephone call [15,17,20–24,31–33,36–40,42–44,47,48,50–52,54,65], and information on time to first pain, patient satisfaction, pain or opioid consumption [20,21,33,36,40,42,54]. Telephone interviews without patient examination for sensory-motor deficit have inherent limitations

in that pain can occur despite successful cPNB e.g. extension of the surgical field outside the area anesthetized by the nerve block or tourniquet pain or other competing sources of pain, while absence of pain can occur despite a failed cPNB e.g. after elective shoulder arthroscopy [16,29], or minor forefoot surgery [21,58,64,66]. With the latter surgeries, minor postoperative may not require cPNB for analgesia beyond 24 h, provided that effective multimodal analgesia is established [67]. Telephone interviews are associated with the recall, information or interviewer bias [27,33,40,42,54].

Other subjective estimators of secondary cPNB failure employed in the literature have been based on retrospective reviews of cumulated opioid dosage or proxy markers of cPNB failure such as pain or discomfort during the recovery period [27,36–38,44,48,65].

Opioid requirement after surgery or the presence of any postoperative pain may be interpreted as cPNB failure [2,8,10,58,67,68]. However, contributing factors in the surgical limb but outside the surgical field like post tourniquet pain and limb positioning or postoperative opioid-induced hyperalgesia may affect postoperative pain and opioid administration as well [5–7].

Distinguishing between postoperative opioid requirement and preexisting chronic opioid use is crucial for using cumulated opioid intake as a marker for cPNB failure. Unfortunately, none of the 33 included studies excluded patients with daily opioid intake, which carries a risk of bias in the estimation of postoperative opioid consumption.

Minor or no postoperative opioid intake may not be used as an accurate method to assess catheter success as opioid-requiring pain after minor surgery can be absent or shorter than the duration of a sPNB or the local infiltration analgesia installed by the surgeon.

B. Objective assessment

Even with objective methods, the internal validity may be reduced by patient-related factors as well as limitations of methodological design such as lack of blinding and randomization. We identified several employed objective estimators of cPNB failures, such as visualization of catheter tip position with ultrasound, MRI of the spread of contrast, and real-time ultrasonographic visualization of the perineural spread of injectate [24–26,30,34,35,46,56]. Ultrasound and MRI are objective patient-independent visualization techniques [24,42,69].

Femoral nerve cPNB failure rate has been assessed in a non-randomized and non-blinded trial by ultrasonographic measurement of the distance from the catheter tip to the target nerve 48 h after knee arthroplasty [56]. No secondary failures were observed, as all catheter tips were assessed to be closer than 3 mm to the femoral nerve (secondary failure was defined as a distance of more than 3 mm). However, it is often difficult if not impossible to accurately assess the catheter tip location with ultrasound. The ultrasonographic procedure itself may cause catheter displacement due to the pressure of the ultrasound probe against the tissues [48]. If a nerve stimulation catheter is used, motor response to electrical nerve stimulation may confirm the catheter tip position during catheter insertion [30,34,35], albeit, residual nerve blockade makes this method unreliable to assess secondary cPNB failure [34]. Ultrasonographic assessment of catheter tip position can be combined with an injection of 5% dextrose in water (D5W), microbubbles, agitated saline, or local anesthetic [25,27,34,35,44,50,70–72]. Comparative studies of techniques for assessment of cPNB failure are lacking [35].

In a volunteer study, catheter failure was evaluated following a standardized physical exercise. The perineural spread was assessed by injection of normal saline under real-time ultrasonographic visualization [26]. After the follow up of 6 h (study duration) the secondary failure rates were 25% for femoral nerve catheters and 5% for interscalene catheters. In another study, the recently described suture-method catheter was evaluated by ultrasound after a standardized physical exercise in healthy volunteers and failed in 27% of cases one hour after insertion [46].

One study combined interscalene ultrasonographic visualization of the perineural spread of local anesthetic injected via the catheter (verifying successful primary catheter placement) followed by a daily assessment of sensation in the C5/C6 dermatomes. The authors observed a 35% failure rate on the second postoperative day [30]. Another study demonstrated a 24% secondary failure rate of interscalene catheters if patients' inability to abduct the shoulder combined with cessation of cold sensation in the deltoid region (axillary and suprascapular nerves) was combined with an ultrasonographic

assessment [38]. Another recent study found a primary failure rate of adductor canal suture-catheters of 17% or 25% depending on catheter insertion method (out-of-plane vs in-plane). The evaluation was made by a combination of sonographic assessment of the spread of injectate of 15 mL lidocaine 1% in the adductor canal, and absent cold sensation in the medial part of the lower leg 15 min after primary placement [25].

A more accurate method to determine whether the catheter is in the therapeutic location is MRI visualization of the perineural spread of injected contrast, which has been used for assessment of failure rate of popliteal sciatic nerve catheters 48 h after major foot surgery [24]. This double-blinded randomized controlled study found a secondary displacement rate of 10% or 40% depending on the catheter insertion technique. In this study, an out-of-plane short-axis technique was associated with fewer failures than the in-plane short-axis technique.

Catheter failure and type of surgery

A. Shoulder surgery

Studies evaluating interscalene catheter failure with objective [26,27,30], as well as subjective [17,20,29,50–54], methods showed a secondary failure rate of 11% [95%CI: 5–16] evaluated after 39 h [95%CI: 21–57] follow up period.

Shoulder surgery is frequently carried out as ambulatory arthroscopy, typically generating moderate to severe pain only the first 24 postoperative hours (e.g. acromioplasty, chondroplasty, decompressions, and rotator cuff repair) [61]. Open shoulder surgery often requires hospital admission for postoperative analgesia [29,61,62]. For effective regional analgesia after shoulder surgery, the suprascapular and axillary nerves from the superior trunk of the brachial plexus need to be anesthetized. If the surgery involves an anterior approach to the shoulder joint, the supraclavicular nerves from the cervical plexus need to be anesthetized as well [61,72].

Discharging patients to their home with interscalene catheters *in situ*, connected to disposable or non-disposable electric pumps for continuous interscalene infusion of local anesthetics after shoulder surgery is a common practice [8,17,58,73–75]. The largest study of patients discharged with interscalene catheters after shoulder surgery included 1505 consecutive patients [74]. Two-thirds of patients had arthroscopic surgery and 86% were discharged on the first postoperative day. However, many patients in this study may have had analgesia from the initial bolus injection of 10–30 mL ropivacaine 0.375–0.75% via the needle prior to catheter insertion. During the data collection retrospectively by telephone interviews at 5–7 days after surgery, the patients reported malfunctions of the pump or accidental catheter misplacement and dislodgements in 13% of cases. However, the injection of 10–30 mL ropivacaine 0.375–0.75% through the needle may have provided analgesia of sufficient duration in some of the cases.

Literature suggests that the failure of interscalene catheters after hospital discharge is common and proportional to the duration of the follow-up. The reported secondary failure rates vary from 5% after 6 h [26], 10–19% after 24 h [20,47] up to 27–35% after 48 h [30,76]. In one study, interscalene catheters were inserted before arthroscopic shoulder surgery and 30 mL of ropivacaine 0.5% was injected via the catheter. By design, catheters were removed immediately after surgery in half of the patients; there was no difference in pain (NRS) between patients with and without infusion via the catheter (NRS 1 [IQR 0–2] vs 2 [IQR 1–4]) during the morning of the first postoperative day, or the second postoperative day [73]. Of note, an interscalene sPNB with 20 mL ropivacaine 0.75% added perineural dexamethasone with multimodal analgesia provided adequate postoperative opioid-free analgesia for up to 39 ± 12 postoperative hours [27,77].

Concerning major shoulder surgery, a meta-analysis from 2018 compared interscalene cPNB and sPNB to rule out the best postoperative analgesia technique [78]. The study included 15 studies from 1970 to 2017 with a certain heterogeneity in local anesthetic choice, use of ultrasound, catheter type, and method of evaluation. Authors considered interscalene cPNB the more effective method of analgesia compared to sPNB because opioid consumption was reduced by more than 50 mg morphine. However, using opioid consumption for estimating catheter failure may be inaccurate. Comparisons

between sPNB and cPNB are only significant when sPNB are performed using the most effective mixture of local anesthetics and adjuvants.

B. Major upper limb surgery

Supra-, infraclavicular and axillary brachial plexus catheters may be indicated for major surgery of the upper limb distal to the shoulder. In a few studies, catheter failure has been investigated as a secondary outcome, evaluated either by subjective pain assessment [20], retrospective chart reviews [38,48], telephone interviews, or questionnaires [20,39,40]. Reported failure rates vary between 6 and 30%, typically after a short follow-up time interval. None of the included studies concerning catheters for major upper limb surgery reported more than 24 h to follow up, making any comparison of the efficacy of cPNB to sPNB difficult. Two studies assessed secondary failure rate based on objective evaluation methods using ultrasound, nerve stimulation and sensory testing [34,35]. However, the observational time was only a few hours after surgery and the failure rate was 22% for infraclavicular catheters [20]. Again, studies with a follow-up shorter than 24 h are not clinically meaningful, as the duration of sPNB can be more than 24 h with long-acting local anesthetic and adjuvants.

Six studies assessed cPNB failure after upper limb surgery [20,34,35,39,40,48]. Only two of these studies used objective evaluation methods with ultrasound, contrast or nerve stimulation [34,35]. The failure rates reported in these 2 studies were 14% and 22% after only a few hours of observation, while 4 studies based on subjective assessments reported cPNB failure in 26%, 19%, 6% and 30% of cases after 24 h (Table 1). In 3 of these 4 studies, the primary catheter failure rate was not assessed, as the first bolus was injected via the needle and not the catheter [20,38,48].

C. Total knee arthroplasty (TKA)

Numerous studies have been published, describing benefits and disadvantages of using sciatic, femoral, saphenous, or adductor canal catheters either alone, in combination, or together with local infiltration analgesia [15,28,31,43,51,56,58,79–87].

In a blinded RCT, the combination of multimodal analgesia with either femoral cPNB or sPNB resulted in equal pain reduction, opioid consumption, length of stay and mobilization at 48 post-operative hours after TKA [82]. Catheter failure rates were not reported. However, 2 other studies have assessed the failure rate of femoral nerve catheters in patients ambulating after TKA. One study evaluated pain scores and opioid consumption at rest and at 45° knee flexion from patient charts on the first postoperative day after TKA and found a 20% failure rate [51]. However, retrospective calculation of cumulative opioid consumption and post-TKA pain, especially during knee flexion, is not accurate in estimating catheter failure rate due to the pain sources originating from non-anesthetized nerves supplying the posterior innervation of the knee [76]. Another study evaluated catheter tip location by ultrasound 6 h after insertion and observed a 25% rate of failure [26].

Catheters inserted in the adductor canal (often - femoral triangle) have been shown to spare the major motor branches from the femoral nerve without significantly reducing the post-TKA analgesic effect compared to a femoral nerve catheter [43,51,56,79,82,88]. Unfortunately, high failure rates of adductor canal catheters have been reported. Four studies evaluated secondary failure rates of adductor canal catheters for post-TKA pain with subjective or inaccurate methods of assessment such as pain, opioid consumption, and inspection for obvious displacement (an inaccurate proxy marker of displacement with a high risk of underestimating the frequency of displacement) at the catheter insertion site [28,37,43,51]. One study employed an objective estimator of secondary failure of adductor canal catheters based on a combination of ultrasound visualization of catheter orifices and testing of sensory anesthesia after injection of a bolus of local anesthetic [25]. However, failure rates of 17% and 50% depending on the catheter insertion method (short-axis, in-plane versus long-axis, in-plane) were observed after just a few hours of observation. All other studies describing saphenous nerve catheter failure used a short-axis in-plane insertion technique except a recent study presenting the “suture-catheter”, inserting the catheter via a hook-shaped needle (like a skin-suture), piercing the skin twice,

allowing secondary repositioning of the catheter. However, the method has not been clinically validated [25].

Addition of a sciatic catheter to a femoral nerve block after TKA impedes ambulation and fails to anesthetize the important contribution from the obturator nerve to the posterior popliteal plexus, innervating the posterior part of the knee capsule. Regardless, sciatic cPNB reduces pain and postoperative opioid administration up to 36 h after surgery [58,80]. No studies have assessed the frequency of sciatic nerve catheter failure after TKA. Sciatic nerve catheters for foot surgery failing 10% and 40% of cases depending on catheter insertion method [24].

D. Major foot and ankle surgery

Although major foot and ankle surgery entails immobilization of the lower limb, high secondary failure rates are reported in the literature. Sciatic nerve catheter failure was evaluated 48 h after surgery with MRI and found to be 10% with short-axis out-of-plane and 40% with short-axis in-plane [24]. This complies with a failure rate of 6% reported for short-axis out-of-plane and 55% with short-axis in-plane reported after 48 postoperative hours in two previous studies using proxy markers of catheter failure [32,37]. The majority of sciatic nerve catheters for pain relief after foot and ankle surgery as reported in the literature were inserted with the short-axis in-plane technique [32,36,42,44,48,54,65].

Out of 11 studies assessing secondary failure rate of sciatic catheters in the literature, 2 studies evaluated the catheters objectively by either MRI or ultrasound visualization of the catheter tip or spread of local anesthetic [24,46]. Failure rates were found in 10%, 16% and 40% of cases depending on the insertion method and catheter type. The remaining 9 studies reported failure rates estimated from subjective assessment methods such as telephone interviews, questionnaires or chart review. Observation time ranged from a few postoperative hours to 3 postoperative days. Mean failure rate among the studies using subjective methods was 16% [CI95%: 9–23] after a mean observational time of 35 h [CI95%: 21–50].

A blinded randomized study compared infusion of ropivacaine vs saline in saphenous nerve catheters after major foot and ankle surgery. All patients had an initial ropivacaine bolus injected immediately after catheter insertion. After 48 h postoperative pain scores and opioid consumption demonstrated no intergroup differences [38]. Thus, it seems adequate to anesthetize the saphenous nerve only for the first 24 h after surgery with a sPNB [21,37,81].

Risk of toxicity due to cPNB failure

Repeated delivery of extra boluses of local anesthetic via a displaced catheter increases the total dose and possibly the risk of LAST [12,63,89]. Migration of the catheter tip into surrounding muscles induces a risk of intramuscular infusion of local anesthetic and myotoxicity [63,90]. Myotoxicity is well described clinically and neurophysiologically in animal models [63,89,90].

Current and future alternatives to cPNB

The most effective adjuvants to local anesthetics are either dexmedetomidine or dexamethasone administered perineurally or IV [19,91–111]. The typical mean duration of postoperative pain relief of a mixture of 0.5% bupivacaine, 1:200,000 epinephrine and 8 mg dexamethasone, is approximately 26 h [19]. Repetition of a sPNB with a long-lasting local anesthetic mixture on the first post-operative day would theoretically provide analgesia for at least 48 postoperative hours. However, concerns regarding the safety of a second sPNB performed in a patient with partially anesthetized nerve structures need to be addressed. Adequate use of monitoring (ultrasound, peripheral nerve stimulation, and pressure monitoring) and training would be mandated.

While the evidence in favor of adding dexamethasone or dexmedetomidine to local anesthetics is mounting, ongoing randomized clinical trials with delayed release formulations, such as liposomal bupivacaine, show promising results [112,113].

Percutaneous electrical peripheral nerve stimulation (PNS) has recently been proposed as an alternative to continuous infusion of local anesthetics for treatment of long-duration acute and severe postoperative pain. A small electrical lead is inserted via a needle under ultrasound-guidance in the vicinity of the target nerve. However, more studies are necessary to determine the risk of primary or secondary failure and cost-efficiency of this, new treatment [83,85,114,115].

Introducing a reversible Wallerian degeneration of the nerve fibers by cryoablation is another method of inducing long-lasting nerve blockade, especially relevant for postoperative cutaneous neuropathy. The cryoablation procedure is not as painful as neurodestructive techniques such as phenol or alcohol blocks but similarly prolongs the nerve block up to several months. However, cryoablation is associated with a risk of injury of motor nerve fibers or mixed nerves. Further research is needed to determine whether cryoablation or PNS has a role in acute postoperative pain management in cases of manifest or anticipated severe postoperative pain [10,116].

Conclusion

Peripheral ultrasound-guided nerve catheters appear to be a common analgesic modality. However, a more standardized methodology in future studies is necessary to more accurately determine their efficacy and failure rate. Our literature review suggests that failure of the nerve catheters is common and clinically significant. Available studies often do not detail the assessment methodology, use subjective proxy methods of assessment, or end the assessment up too soon to assess the failure rate properly. As an example, the follow-up period of the 2711 catheters included in this review was generally short - only 35 [95%CI: 28–42] postoperative hours.

Studies based on objective imaging techniques for assessment of secondary failure reported higher failure rates compared to subjective methods (21% +/- 15% vs 12% +/- 10%, $p < 0.05$). This suggests that subjective methods of assessment tend to underestimate the incidence of cPNB failure.

Local anesthetics with added adjuvant has consistently shown significant opioid reduction and even absence of opioid requirements after various types of surgery. Along with repetitive sPNB using local anesthetics with adjuvants as well as delayed release formulations, or new interventional alternatives, postoperative pain relief with continuous peripheral nerve blocks may become obsolete in the near future.

Practice points

- When placing perineural catheters it is important to objectively document the catheter tip using ultrasound
- When interpreting literature on the efficacy of perineural catheters, read the methods to assure that placement of the catheter was confirmed by imaging (objective assessment).
- Analgesic benefits of perineural catheters should be interpreted within the context of the methods used to assess the analgesic outcome

Research agenda

- Further research on catheter efficacy using objective methods of assessment is needed
- Methodology of assessment should be specified in every future study evaluating catheter efficacy
- Studies comparing catheters vs extended release local anesthetics are needed to better assess the efficacy of each method.

Financial disclosure

None.

Conflicts of interest

Dr. Hadzic has consulted and advised for Philipps, Pacira and BBraun Medical. His recent industry-sponsored research include Pacira Pharmaceuticals and Heron Therapeutics. Dr. Hadzic receives royalty income from BBraun Medical.

Acknowledgment

The study was funded by the A.P. Møller and Chastine Mc-Kinney Møller Foundation for General Purposes and the Salling Foundation. The content is solely the responsibility of the authors.

Appendix A

A literature search was made using the following terms: “continuous nerve block” OR “continuous nerve blockade” OR “continuous regional anesthesia” OR “continuous analgesia” OR “continuous anesthesia” OR “continuous peripheral nerve block” OR “continuous peripheral nerve blockade” OR “continuous peripheral nerve catheters” OR “peripheral nerve block” OR “peripheral nerve blockade” OR “peripheral nerve catheter” OR “peripheral nerve catheter placement” OR “perineural catheter” OR “perineural catheter insertion” OR “perineural catheter placement” OR “perineural catheter technique” OR “nerve catheters”) AND (“failure” OR “fail” OR “dislodge” OR “dislocation” OR “displacement” OR “misplacement” OR “malfunction” OR “complication” OR “morphine consumption”) as found in the title or abstract under the Medical Subject Heading (MeSH) “Anesthesia and Analgesia”.

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