Peripheral regional anaesthesia and outcome: lessons learned from the last 10 years

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Editor’s key points
- The authors reviewed the extensive literature regarding outcome following peripheral regional anaesthetic techniques.
- Improvements in postoperative pain and surgical pathway efficiency were noted. Complications were rare.
- Long-term effects were not apparent, although further work is needed in this area.

Background. Our aim was to review the recent evidence for the efficacy of peripheral regional anaesthesia.

Methods. Following a systematic literature search and selection of publications based on prospectively agreed upon criteria, we produced a narrative review of the most commonly performed peripheral regional anaesthetic blocks for surgery on the upper limb, the lower limb, and the trunk. We considered short-term and longer-term benefits and complications among the outcomes of interest.

Results. Where good quality evidence exists, the great majority of the blocks reviewed were associated with one or any combination of reduced postoperative pain, reduced opioid consumption, or increased patient satisfaction. For selected surgical procedures, the use of blocks avoided general anaesthesia and was associated with increased efficiency of the surgical pathway. The exceptions were supraclavicular block, where there was insufficient evidence, and transversus abdominis plane block, where the evidence for efficacy was conflicting. The evidence for the impact of the blocks on longer-term outcomes was, in general, inadequate to inform clinical decision making. Permanent complications are rare.

Conclusions. The majority of peripheral regional anaesthetic techniques have been shown to produce benefits for patients and hospital efficiency. Further interventional trials are required to clarify such benefits for supraclavicular block and transversus abdominis plane block and to ascertain any longer-term benefits for almost all of the blocks reviewed. Permanent complications of peripheral regional anaesthetic blocks are rare but accurate estimates of their incidence are yet to be determined.

Keywords: nerve block; outcome studies; postoperative complications; postoperative pain

Peripheral regional anaesthesia is an integral component of modern perioperative care. The worldwide popularity of peripheral regional anaesthesia has increased over the last decade mainly because of innovative and more reliable needle location methods, principally based on ultrasonography. Such highly sophisticated technology enables an effective blockade of almost any peripheral nerve to be achieved, resulting in expanded opportunities for regional anaesthetic blocks. Peripheral regional anaesthesia can be performed with minimal technological requirements using basic techniques (e.g. fascia iliaca compartment blocks).

The improved capability of anaesthetists to achieve a high success rate with peripheral regional anaesthetic techniques has coincided with an increasing number of multimorbid surgical patients, who are generally perceived to benefit most from peripheral nerve blocks. On the one hand, such patients may benefit from avoiding general anaesthesia, while neuraxial techniques are recognized to be associated with albeit rare serious complications, especially in patients on anticoagulant or antiplatelet therapy.

A large number of publications describe various aspects of peripheral regional anaesthesia techniques in daily clinical practice. There has been a lot of debate within the literature concerning the relative merits of nerve location techniques, but our focus will be on the outcome of the block per se rather than how the block was achieved. Even so, the heterogeneity of the literature in this field significantly contributes to the difficulty of practitioners attempting to define the
clinical value of peripheral nerve blocks and precludes the use of formal statistical comparison of combined study data. Thus a clear narrative overview of the available scientific data may be the best approach to help in making a well-balanced risk–benefit analysis for the use of different peripheral regional anaesthesia techniques.

Thus the present review article was designed to present a weighted summary of the available outcome data in the field of peripheral regional anaesthesia. Outcome was defined primarily as effectiveness, which summarizes clinical endpoints such as pain reduction, reduced demand for systemic analgesic drugs, reduced need for general anaesthesia, and patient satisfaction. Secondary outcomes were functional recovery from the surgical procedure and complications. For each block we also included a section entitled ‘Nice to know’, which includes interesting findings for specific blocks that could not easily be fitted into one of the other categories and reflects again the great variety of endpoints included in studies of peripheral nerve blocks.

Methods
Source of information
Human studies in the field of upper extremity, lower extremity, and trunk block techniques with a publication date between October 4, 2003, and October 3, 2013, were extracted from PubMed, with reference lists of retrieved articles searched for additional trials or reports. For upper extremity blocks, interscalene, supraclavicular, infracervical, and axillary brachial plexus techniques were included. For lower extremity blocks, femoral, saphenous and adductor canal, sciatic, and psoas compartment techniques were considered. For blocks of the trunk, cervical, intercostal, transverse abdominal plane, rectus sheath, and ilioinguinal/iliohypogastric nerve block techniques were considered. Studies were excluded if children (<18 yr) were the subjects.

The following search terms were used: interscalene nerve block, interscalene nerve blockade, interscalene plexus block, interscalene brachial plexus block, interscalene brachial plexus blockade, supraclavicular nerve block, supraclavicular nerve blockade, supraclavicular plexus block, supraclavicular plexus blockade, supraclavicular brachial plexus block, supraclavicular brachial plexus blockade, infraclavicular nerve block, infraclavicular nerve blockade, infraclavicular plexus block, infraclavicular plexus blockade, infraclavicular brachial plexus block, infraclavicular brachial plexus blockade, axillary nerve block, axillary nerve blockade, axillary plexus block, axillary plexus blockade, axillary brachial plexus block, axillary brachial plexus blockade, sciatic block, sciatic blockade, sciatic nerve block, sciatic nerve blockade, femoral block, femoral nerve block, femoral nerve blockade, saphenous block, saphenous blockade, saphenous nerve block, saphenous nerve blockade, adductor canal block, adductor canal blockade, psoas compartment block, psoas compartment blockade, cervical plexus block, cervical plexus blockade intercostal block, intercostal blockade, intercostal nerve block, intercostal nerve blockade, ilioinguinal block, ilioinguinal blockade, ilioinguinal nerve block, ilioinguinal nerve blockade, iliohypogastric block, iliohypogastric blockade, iliohypogastric nerve block, iliohypogastric nerve blockade, transversus abdominis plane block, transversus abdominis plane blockade, rectus sheath block, and rectus sheath blockade. The reference lists of the included articles were examined to ensure that no relevant literature was missed.

Data selection
Decisions for listing articles were made according to the recommendations for narrative reviews by McAlister. We ranked randomized controlled trials (RCT) highest, followed by other trials and reports when no superior, broad evidence base could be discerned. Technical reports, anatomical descriptions, dose-finding studies, studies comparing peripheral nerve blocks, studies comparing various approaches, studies comparing different local anaesthetics or different local anaesthetic concentrations or additive perineural drugs were excluded. We included articles in any language.

All articles were reviewed for the following outcomes: effectiveness (pain reduction, reduced demand for systemic analgesic drugs, reduced need for general anaesthesia, and patient satisfaction), functional recovery, and complications (e.g. nerve injury). Other relevant findings (e.g. length of hospital stay) were also recorded and summarized under the subheading ‘Nice to know’.

Results
Figure 1 summarizes the results of the study selection process.

Upper extremity blocks
Interscalene approach
Twenty-eight (17 RCTs with a total of 910 patients) of 344 articles on outcome data regarding interscalene plexus blocks with a total of 26 288 patients where identified as suitable for this review.

Effectiveness. When compared with placebo in patients undergoing ‘major shoulder surgery’, interscalene block significantly reduced the consumption of rescue medication after surgery, improved patient satisfaction, and even produced pain relief during movement for up to 3 days after a single-shot injection of local anaesthetic. Patient satisfaction in 1319 patients was reported to be 99%, while 97.8% of these patients would choose the same procedure again. In addition, interscalene block was found to be associated with less need for intraoperative opioids.

In patients undergoing ‘moderately painful shoulder surgery’, less pain [median (range) nominal rating scale (NRS) 0 (0–5) vs 3 (0–6)], respectively, on postoperative day 1; $P<0.001$, reduced opioid consumption (67% of subjects receiving ropivacaine required no supplemental opioid compared with 13% of subjects in the placebo group; $P=0.012$), less sleep disturbance, and a higher patient satisfaction compared with placebo was described.

Functional recovery. For shoulder surgery, interscalene block compared with systemic analgesia was associated with
a reduced Constant score\(^\text{10}\) (a multimodal scoring system that evaluates pain, daily life activity, strength, and range of motion) and better postoperative external rotation of the shoulder on the first postoperative day.\(^\text{5}\)

Complications. The incidence of persistent neurological complications ranged from 0 to 4.4%,\(^\text{11–13}\) with a high incidence of hoarseness (31%) and dyspnoea (12%).\(^\text{14}\) In a large review, the rate of neuropaxia after interscalene brachial plexus block was 2.84%, with no cases of permanent neurological injury.\(^\text{13}\) An analysis of the time course of neurological complications following peripheral nerve blocks for elective orthopaedic surgery, with a focus on interscalene blocks, showed a spontaneous resolution of symptoms from 8.2% on day 1 to 3.7% at 1 month to 0.6% at 6 months.\(^\text{15}\) From a large single-centre database including 9069 nerve blocks comprising predominantly interscalene block procedures (\(n=4682\)), only one seizure and no nerve injuries were reported.\(^\text{16}\)

Details of complications reported in eight studies are summarized in Table 1.

Nice to know. Ten articles comparing interscalene block with subacromial infusion of local anaesthetics were identified.\(^\text{17–26}\) Single subacromial injection of local anaesthetics results in

![Fig 1 Study selection process.](https://academic.oup.com/bja/article-abstract/114/5/728/235317)
similar postoperative pain scores, analgesic consumption, and costs compared with single-shot interscalene block.

Subacromial infusion was one of the most common procedures performed by sports physicians and orthopaedic surgeons, but subacromial and intra-articular local anaesthetic injection has been associated with catastrophic chondrolysis and is no longer recommended. Meanwhile the American Academy of Orthopedic Surgeons warned their members to avoid intra-articular continuous infusions because of the high risk of chondrotoxicity.

In favour of interscalene block over subacromial infusion, some studies report a short-lived comparative reduction in pain at rest and during exercise after surgery, reduced analgesic consumption, and less emesis after interscalene block.

Economic benefits have been shown for interscalene nerve blocks: lower costs of nerve block compared with general anaesthesia, reduced anaesthesia time (from the patient’s arrival in the operating theatre department until readiness for positioning plus time from the end of surgery to the patient’s discharge from the department), and a shorter stay in the post-anaesthesia care unit (PACU) and in the hospital.

Eleven non-RCTs including 25,378 patients suggest success rates for the interscalene approach of 97–99.8%. The practice of performing interscalene block under general anaesthesia is criticised in the literature, but in 910 patients scheduled for shoulder surgery, success rate was 97%, while in another study of 1319 patients receiving this kind of block during general anaesthesia, a success rate of 99.6% was reported. Such high success rates have to be treated with caution because of possible publication bias: success rates tend to be published by centres where experience is greatest and they may not be representative. Indeed, it is hard to envisage journal reviewers and editors being enthusiastic about a submitted article that reported a success rate that did not at least match that in other reports.

Summary statement. Interscalene brachial plexus block provides superior pain therapy and greater patient satisfaction compared with other analgesia techniques. The reported incidence of complications would be sufficient to cause concern for some anaesthetists and/or patients, but it is our opinion that the relatively high incidence of complications in these studies is associated with high volumes of local anaesthetic solutions, which have been shown to be unnecessary in recent publications. Alternative local anaesthetic techniques for shoulder surgery, such as subacromial infusion, cannot be recommended.

Supraclavicular approach

There is only 1 of 134 articles reporting outcome data for supraclavicular brachial plexus blocks that was found suitable for this review. Most of the published articles were technical descriptions, prospective cohort studies, and discussions of different additives. Six articles provided data on success and complication rates and are therefore discussed. These articles describe ultrasound guidance as an essential technique for high success and low complication rates. No data about effectiveness or functional recovery are available.

Complications. In a prospective clinical registry of 654 supraclavicular blocks for shoulder arthroscopy, no vascular puncture, intravascular injection, pneumothorax, or permanent nerve injury has been reported. These results were supported by 510 consecutive cases and 104 retrospectively reviewed patient charts of ultrasound-guided supraclavicular blocks.

<table>
<thead>
<tr>
<th>Type of surgery</th>
<th>Number of patients</th>
<th>Complication</th>
<th>Incidence, %</th>
<th>Reference</th>
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<tr>
<td>Arthroscopic shoulder surgery</td>
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<td>Return to care</td>
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<td>Neuropraxia</td>
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with high success and very low complication rates. The incidence of hoarseness in the PACU was 22% and dyspnoea occurred in 7% of patients. These data are comparable to those reported for interscalene brachial plexus block.

Vulnerable structures such as the pleura and the supraclavicular artery are in close proximity to the very dense nerve structures in this region and thus the supraclavicular approach is often described as more likely to be associated with complications compared with other approaches to the brachial plexus. However, no patient suffered from postoperative neurological complications at follow-up in 17% of patients where intraneural injection had been identified.38

Nice to know. In a prospective trial, 12 patients with upper extremity emergencies received an ultrasound-guided supraclavicular brachial plexus block compared with standard procedural sedation. The length of stay in the emergency department was significantly reduced in the regional anaesthesia group [106 min (95% CI 57, 155) vs 285 min (95% CI 228, 343)], whereas patient satisfaction was high in both groups.39

Supraclavicular brachial plexus block has been associated with a high incidence of phrenic nerve block,40 but it has been claimed that reducing the volume of local anaesthetic to 10 ml can decrease the incidence of phrenic blockade without impairing brachial plexus block success rate.41 However, formal dose-finding studies would suggest that 10 ml of local anaesthetic is insufficient to produce a clinically acceptable success rate for supraclavicular block.42 43

Summary statement. In view of the limited data for this technique, recommendations based on published data cannot be provided. As with interscalene blockade, it is likely that the risk of some complications will be increased with increasing doses of local anaesthetic.

Infracavicular approach

Only one RCT and five non-randomized trials out of 195 articles were identified for the infracavicular approach.

Effectiveness. After hand and wrist surgery, fewer patients with an infracavicular block had pain [visual analogue scale (VAS) >3] on arrival at the PACU (3%) compared with those who had received general anaesthesia (43%). None of the patients who had received regional anaesthesia requested treatment for pain while in the hospital, compared with 48% of patients in the general anaesthesia group. Patient satisfaction was higher when operated on under nerve block.44

Complications. Four cases of neurological injury were detected in 627 infracavicular nerve blocks, but there was a complete resolution of symptoms in each case. Two possible cases of local anaesthetic toxicity occurred. Interestingly, there was no apparent difference in the incidence of complications between experienced and non-experienced operators. The infracavicular block was described as safe and effective when no intraoperative or immediate postoperative complications were noted by Keschner and colleagues in 248 block procedures. Similar to the interscalene and supraclavicular approaches, reduced or paradoxical ipsilateral hemidiaphragmatic movement was observed (26%) and Horner’s syndrome was seen in 12% of 35 patients.47 Using the nerve stimulation technique, vascular puncture was described with an incidence of 6.6%.48

Nice to know. For ambulatory surgery, the time to meet discharge criteria and actual discharge times were shorter for patients with infracavicular nerve blocks (100 (SD 44) and 121 (SD 37) min) compared with those in the general anaesthesia group (203 (SD 91) and 218 (SD 93) min).45 In addition, significantly more outpatients who received infracavicular plexus block met the criteria to bypass the PACU.

In 1146 cases of sonographically guided infracavicular brachial plexus block, arterial punctures occurred in 8 (0.7%) patients: there were no reported cases of nerve injury, pneumothorax, or local anaesthetic toxicity.49

Summary statement. The infracavicular approach to the brachial plexus provides good short- and long-term pain relief and shorter discharge times when compared with general anaesthesia. Similar complication rates are reported as described for the more proximal approaches, and again the volume of local anaesthetic may be important. Vascular puncture is a risk, especially if nerve stimulation is used as the needle location technique.

Axillary approach

Although numerous studies about technical (nerve stimulation vs ultrasound) or pharmacological (different local anaesthetic concentrations and volumes, usage of additives) comparisons have been published, only two RCTs out of 298 reviewed articles report outcome data for brachial plexus blocks in the axillary region, with a total of 130 patients. No data on functional recovery for this nerve block are available.

Effectiveness. Comparing ultrasound-guided axillary block to general anaesthesia for upper limb trauma surgery, the nerve block led to significantly lower VAS pain scores in the recovery room and 2 h and 6 h after the operation.50

For hand surgery, the time to first analgesic request was longer in patients receiving an axillary block and opioid consumption until discharge was significantly reduced. Pain ratings measured at 30, 60, 90, and 120 min after surgery were lower and postoperative nausea and vomiting in the hospital occurred less often compared with patients in the general anaesthesia group. However, on postoperative days 1, 7, and 14 there were no differences in pain, opioid consumption, adverse effects, Pain-Disability Index, or patient satisfaction.51

Complications. In a group of 230 patients who received axillary block while sedated, 2.6% had symptoms of nerve injury in the postoperative period. Most patients recovered fully within several weeks, but one patient had permanent nerve damage.52 The rate of neuropathy after axillary brachial plexus block in a large review was 1.48%, without any case of permanent neurological injury.13

Evaluating inflammation and infection complications of 2285 perineural catheters, of which 600 were sited in the axillary region, local inflammation occurred in 5.0% and infection
in 3.8% (4.2 and 3.2%, respectively, for all catheter sites), with an increasing incidence after longer duration of catheter placement. Toxic drug reactions or axillary haematoma with transient neurological deficit were rare complications. Obesity was identified as a risk factor for an increased complication rate.

**Nice to know.** Patients receiving an ultrasound-guided axillary block bypassed the recovery room more frequently (100 vs 0%, P < 0.0001) and attained hospital discharge criteria earlier (30 vs 120 min, P < 0.0001) compared with those receiving general anaesthesia. In a separate study, patients undergoing ambulatory hand surgery had a shorter stay in the PACU after receiving an axillary nerve block compared with those patients having general anaesthesia.

Several articles relate training in and experience with axillary block to outcome. The success rate and incidence of vascular puncture are dependent on the experience of the operator, while learning curves are dependent on the technique that is used for the block procedure as well as access to and frequency of clinical learning opportunities in the presence of an appropriate trainer. It has been stated that high success rates of 93–98% in different retrospective studies with more than 6500 patients can only be achieved after intensive training.

An ultrasound-guided technique was associated with improved patient satisfaction even during the early institutional transition period from nerve stimulation to ultrasound guidance.

**Summary statement.** Despite the clinical popularity and a large number of studies regarding axillary brachial plexus blockade, published outcome data are scarce. Although short-term pain management is improved, no long-term effects were demonstrated. Permanent nerve damage is described for axillary plexus blocks.

**Lower extremity blocks**

**Femoral nerve**

Femoral nerve block is one of the most common and best evaluated nerve blocks of the lower extremity. Forty-seven of 247 articles (42 RCTs) including 4522 patients were identified to be suitable for this review. Major indications for femoral nerve block were total knee arthroplasty, one of the most painful orthopaedic surgical procedures (28 studies), anterior cruciate ligament reconstruction (7 studies), and hip surgery (3 studies).

**Effectiveness.** For knee arthroplasty, continuous femoral nerve block provided improved pain control during rehabilitation compared with epidural anaesthesia. Only one study reported improved pain control with epidural anaesthesia over femoral nerve block. However, compared with femoral nerve block, combined spinal–epidural anaesthesia provided improved pain therapy for the first 2 days after surgery.

When compared with placebo, continuous femoral nerve block had no effect on the incidence of chronic postsurgical pain following total knee arthroplasty. However, femoral nerve block led to reduced postoperative opioid consumption, with improved pain scores and improved patient satisfaction.

Adding continuous femoral nerve block to spinal anaesthesia is not associated with statistically significant differences in morphine consumption, pain at rest, or during movement compared with spinal anaesthesia alone. However, patients with combined spinal anaesthesia and femoral nerve block were shown to have fewer perioperative side effects, including nausea and vomiting. Consequently, patient satisfaction was improved. Administration of intrathecal morphine improved pain scores compared with femoral nerve block, but also caused itching as a common side effect.

In patients undergoing total knee arthroplasty, two studies found improved pain therapy with femoral nerve block compared with local anaesthetic infiltration, whereas two other studies did not confirm the superiority of femoral block regarding patient-controlled morphine consumption. A further study found reduced opioid consumption after local and periarticular local anaesthetic injections compared with femoral nerve block.

When comparing femoral nerve block with patient-controlled opioid administration for analgesia after total knee arthroplasty, better pain control, less intraoperative and postoperative morphine consumption, and greater patient satisfaction with less work for nursing staff has been demonstrated. However, one study found superior pain relief with patient-controlled opioid.

Continuous femoral nerve block seems to be superior to a single-shot femoral block in terms of postoperative opioid requirements and a reduction in emesis or antiemetic use, although there was no effect on long-term outcome (after 2 yr).

For anterior cruciate ligament reconstruction, continuous femoral nerve block was found to be superior to wound infusion, with reduced pain scores at rest and during movement and less opioid consumption in one study but not in others. Continuous femoral nerve block was associated with less rebound pain and reliably kept pain scores below the moderate-to-severe pain threshold for the first 4 days. Whereas preoperative intra-articular analgesia and femoral nerve block do not differ with regard to the quality of postoperative analgesia, postoperative intra-articular analgesia seems to be less effective.

When used to treat pain following proximal, distal or diaphyseal femoral fractures, or severe knee injury, femoral nerve block reduced pain scores and anxiety levels compared with systemic analgesia. In addition, the incidence of complications was reduced when nerve block was initiated in the emergency department.

For femoral neck fracture, a variation of femoral nerve block, the fascia iliaca compartment block using a high volume of local anaesthetic, provided improved analgesia compared with systemic analgesia. For hip fracture repair, a frequently performed operation in elderly patients, femoral nerve block did not show any advantage over other methods of pain management and did not improve long-term outcome.
In patients undergoing hip arthroscopy, the use of femoral nerve block led to a decreased incidence of nausea and improved patient satisfaction compared with systemic analgesia. For unilateral total hip arthroplasty, no advantage of femoral nerve block could be detected compared with epidural anaesthesia or patient-controlled opioid administration. However, typical procedure-related side effects (nausea/vomiting, urinary retention, arterial hypotension) occurred less frequently when employing peripheral regional anaesthesia.

Only one RCT reported on the effects of continuous femoral nerve block in non-orthopaedic surgery. In that study the nerve block improved pain management in patients undergoing skin grafts for burn injuries, with reduced morphine consumption within the first 72 h postoperatively.

Functional recovery. The data concerning the effect of femoral nerve block on functional recovery following total knee arthroplasty are conflicting. Whereas continuous femoral nerve block provided a better or at least comparable functional outcome compared with epidural anaesthesia/combined spinal epidural anaesthesia, no significant decrease in knee stiffness and functional disability was reported when femoral block was compared with placebo.

When femoral nerve block was assessed against local anaesthetic infiltration, improved functional outcome was suggested in three studies, but one study even showed a functional improvement for the local infiltration group. Similarly, when a comparison was made against patient-controlled analgesia, one study suggested improved mobility after femoral block, whereas another found improved rehabilitation when employing patient-controlled analgesia. Following hip fracture repair, mobilization was faster when the anaesthetic technique included a femoral nerve block.

Complications. In general, femoral nerve block is described as a safe technique. Based on a large prospective analysis including more than 1400 patients, although minor incidents (hypoesthesia, numbness, paraesthesia, and bacterial colonization of catheters) occurred quite frequently, no clinically relevant complications were reported for the majority of cases. Major neurological and infectious adverse events were very rare. Even in elderly patients undergoing hip fracture repair, no relevant adverse effects of femoral nerve block were mentioned. The incidence of neuropathy following femoral plexus block in a large-scale review was 0.3%, with one case of permanent neurological injury. The incidence of procedure-related side effects after periarticular injection or femoral nerve block seems to be similar.

Nice to know. As for all peripheral nerve blocks, the quality of the invasive procedure has to be discussed. There is no standardized way of performing these blocks regarding technique (landmark, nerve stimulation, ultrasound), needle, and kind, concentration, and volume of local anaesthetic.

Summary statement. Based on a large number of studies, this nerve block can be regarded as a safe technique, providing pain relief after knee surgery that is superior to wound or intra-articular infiltration. However, chronic postsurgical pain is not affected by femoral nerve blockade. For pain therapy after hip fracture, the fascia iliaca compartment block is effective, whereas the standard femoral block is not.

Saphenous nerve

Eight RCTs and one feasibility study out of 39 articles including a total of 367 patients reported outcome data for saphenous nerve or adductor canal blocks. No block-related complications were mentioned.

Effectiveness. Adductor canal block for total knee arthroplasty provided better pain therapy when calculated as the area under the curve for the interval 1–6 h, with reduced opioid consumption compared with placebo, but without a reduction in the need for opioids. Only one study suggested a reduction in patient-controlled opioid consumption. Superiority for the analgesic effect of adductor canal block has not been confirmed for arthroscopic anterior cruciate ligament reconstruction.

Functional recovery. No differences in mobility time or 1 week Lysholm knee scores were found after arthroscopy in patients receiving saphenous nerve block compared with placebo, whereas patients displayed less need for external support while walking following meniscectomy compared with placebo.

After total knee arthroplasty, significantly more patients receiving a continuous saphenous nerve block combined with local infiltration were able to ambulate compared with those receiving local infiltration alone. In addition, blockade of the adductor canal significantly enhanced ambulation as assessed by the Timed Up and Go (TUG) test.

Nice to know. In a feasibility study, the saphenous nerve could be reliably blocked using ultrasound guidance in patients undergoing ankle or foot surgery.

Quadriiceps strength and the risk of falls are important clinical considerations for the postoperative period. Adductor canal block performed in volunteers preserved quadriiceps strength and balance scores, whereas femoral nerve block did not.

Summary statement. This purely sensory nerve block provides effective pain therapy after total knee arthroplasty and knee arthroscopy, lacking the undesirable side effects of motor blockade caused by femoral nerve blockade.

Sciatic nerve

Twenty-seven (23 RCTs) of 257 articles including 3469 patients reported outcome data for sciatic nerve blocks. Major indications for sciatic or combined femoral and sciatic nerve blocks were various knee operations.

Effectiveness. Eleven articles focused on total knee arthroplasty. Compared with patient-controlled intravenous analgesia,
Peripheral nerve blocks provided better analgesic quality, particularly dynamic pain reduction, reduced opioid consumption with improved patient satisfaction, reduced clinical signs of inflammation, and decreased inflammatory mediators.

Compared with periarticular infiltration, a combined femoral and sciatic nerve block showed similar effects on pain and morphine consumption. Compared with spinal anaesthesia, peripheral nerve blockade led to improved analgesia. When patients received epidural anaesthesia or peripheral nerve block for total knee replacement, there were no clinically relevant differences in pain, opioid requirements, or patient satisfaction. The onset of analgesia was delayed compared with the neuraxial technique, but the time to first analgesic needed was longer.

Eight articles have been published with respect to arthroscopic knee surgery employing sciatic or combined sciatic blocks. Compared with spinal anaesthesia, peripheral nerve blocks show similar or even better pain relief. The need for opioids during the procedure and patient satisfaction were similar, with an earlier postoperative voiding of urine after the sciatic block. However, there is an increased incidence of postoperative nausea and vomiting (odds ratio 2.8) for combined lumbar plexus and sciatic nerve block compared with spinal–femoral nerve block. In comparison with epidural anaesthesia, sciatic nerve block showed a delayed onset, but also less need for rescue medication. Intraoperatively, more opioid supplementation was required when femoral nerve block together with anterior sciatic nerve block was used.

For hallux valgus repair, mid-foot block and sciatic nerve block provided comparable postoperative analgesia, with slight advantages for the foot block because of reduced time to ambulation. Compared with oral medication, posterior tibial nerve blocks led to significantly lower pain scores at 4, 12, and 24 h postoperatively and less need for rescue analgesia, as well as a high level of patient satisfaction.

For open repair of calcaneal fractures, either presurgical or postsurgical sciatic nerve blocks resulted in reduced pain scores and less morphine consumption. For foot surgery performed under spinal anaesthesia, combined sciatic and saphenous nerve block provided better pain reduction on the first and second postoperative days (P=0.001; e.g. worst pain on the first postoperative day VAS=5 vs VAS=7.5) and a trend towards reduced sleep disturbances compared with placebo injection. For lower extremity orthopaedic surgery, combined sciatic–lumbar plexus nerve block showed a similar effect as spinal anaesthesia, a longer onset time, but also a longer duration of nerve block.

Using a combined sciatic and femoral nerve block, fewer ST alterations were seen compared with general anaesthesia in peripheral vascular surgery. For leg amputation, no benefit has been shown for sciatic nerve block compared with general anaesthesia.

Functional recovery. For patients with total knee replacement, functional outcome after combined sciatic and femoral nerve block was similar to periarticular infiltration or epidural anaesthesia. Compared with spinal anaesthesia, this combined block led to increased knee flexion and extension scores.

Complications. Using a combined femoral and sciatic nerve block instead of an epidural catheter for patients undergoing total knee replacement did not effect the incidence of complications or side effects. Using a peripheral nerve block is less likely to cause a severe neuraxial complication.

Nice to know. For total knee replacement, the length of the hospital stay did not differ for patients receiving peri-articular infiltration or epidural analgesia compared with a combined femoral–sciatic nerve block. Following arthroscopic knee surgery, the discharge from the PACU was earlier, with a slight improvement in Aldrete score compared with epidural anaesthesia: an earlier readiness for discharge was also shown compared with general anaesthesia.

In addition to improved patient satisfaction, combined sciatic–femoral nerve blocks for total knee replacement yielded better surgeon satisfaction scores compared with epidural anaesthesia.

The cost of disposable items and drugs for patients undergoing knee arthroscopy was similar for sciatic nerve block compared with general anaesthesia.

Summary statement. Most of the large number of publications describe effective pain therapy after surgery, reduced opioid requirements, and improved patient satisfaction.

Psoas compartment
Six of 28 articles reported outcome data for psoas compartment block with a total of 343 patients (5 RCTs and 1 descriptive case series).

Effectiveness. Patients receiving levobupivacaine infusion via a psoas compartment catheter following total knee arthroplasty had similar pain scores but needed significantly less morphine than those receiving saline.

Four studies investigated the use of psoas compartment block in hip surgery. Psoas compartment block provided effective pain therapy for hip surgery in a prospective, descriptive, non-randomized study. Compared with an intrathecal combination of morphine, fentanyl, and bupivacaine for postoperative analgesia after primary hip arthroplasty, no statistically significant differences regarding pain scores during the first 24 h, satisfaction scores, or tramadol consumption were reported. Assessed against intravenous morphine/ketorolac infusion, an opioid-free continuous psoas compartment block provided similarly effective postoperative analgesia at rest and during physiotherapy after total hip arthroplasty. Less rescue analgesia was needed, with lower pain scores at rest and after mobilization, and less nausea and vomiting was observed. Compared with intravenous morphine patient-controlled analgesia, psoas compartment block did not result in reduced morphine consumption or lower pain scores, either at rest or during mobilization.
**Cervical plexus**

Outcome data were available in 12 of 56 articles on cervical plexus blocks with a total of 4632 patients. Data on complications or functional recovery were not reported in the articles extracted.

**Effectiveness.** Nine of the identified articles report the use of cervical plexus block for thyroid surgery,144–152 and these suggested superior postoperative pain control144–147 152 and a reduction in narcotics,146 148 149 headache,148 and postoperative nausea and vomiting144 146 148 for the block compared with placebo. In addition, patient satisfaction was significantly higher when cervical plexus block was employed.148 However, two randomized, double-blind controlled studies did not confirm the reduction of pain scores or decreased intraoperative opioid consumption.150 151

For carotid endarterectomy, a significant and clinically relevant reduction in morphine consumption and lower pain scores as well as substantially higher patient satisfaction using superficial cervical plexus block compared with general anaesthesia was demonstrated.153 The GALA Trial Collaborative Group compared carotid endarterectomy surgery under general or local anaesthesia in a parallel group, multicentre RCT of 3526 patients from 95 centres in 24 countries. The primary outcome was prediction and avoidance of perioperative stroke, which was found not to be significantly different. Furthermore, the two groups did not significantly differ for quality of life or length of hospital stay.154 The local anaesthesia group was superior with regards to cost-effectiveness.155 It has to be emphasized that the regional anaesthetic techniques used in the GALA study were not standardized between centres (different techniques and local anaesthetic solutions).156

No differences in pain scores or the incidence of nausea and vomiting could be shown when cervical plexus block was performed in patients undergoing infratentorial or occipital craniotomy.157

**Nice to know.** A study that included 159 patients undergoing thyroid surgery found that pain control was similar whether cervical plexus block was performed before or after the surgery.145

Data examining the effect of cervical plexus block on the length of hospital stay were contradictory. One study showed a significant reduction in hospital stay with cervical plexus block,146 but another found no difference compared with the placebo group.145

**Summary statement.** Cervical plexus blockade provides high patient satisfaction for thyroid surgery and carotid endarterectomy. No differences in the incidence of stroke and death have been observed compared with general anaesthesia for carotid endarterectomy.

**Intercostal nerve block**

Nine RCTs out of 102 articles reported outcome data for intercostal nerve blocks with a total of 582 patients: in most cases the nerve blocks were compared with placebo. No data on success rate and the incidence of complications were available. The following indications for intercostal blockade are described in the literature: rib fractures, thoracotomy, retroperitoneal surgery, abdominal surgery.

**Effectiveness.** One of the most important indications for intercostal blocks is rib fractures. It has been shown that continuous intercostal nerve blocks lead to better pain control in these patients.158

For patients undergoing laparoscopic cholecystectomy, pain severity159 and postoperative morphine consumption160 were significantly reduced by intercostal nerve blockade. In addition, the duration of the need for patient-controlled analgesia was significantly decreased.160 With open cholecystectomy, intraoperative inhalation anaesthetic use was significantly reduced by the use of intercostal nerve blocks.161 In cardiac surgery162 163 and after major lung resections,164 pain scores were significantly improved with a lower systemic analgesic requirement when compared with placebo.

However, compared with thoracic epidural analgesia, intercostal nerve blockade for thoracotomy was associated with higher resting and dynamic pain scores.165 166

**Functional recovery.** Compared with historic controls, continuous intercostal nerve block significantly improved pulmonary function after rib fractures.158 However, this did not hold true for cardiac surgery.163 For thoracotomy, intercostal nerve blocks compared with thoracic epidural analgesia did not lead to an improvement in respiratory function,165 whereas for lung surgery epidural analgesia proved superior with respect to pulmonary function on the second postoperative day, albeit without a significant difference in pulmonary complications.166

**Nice to know.** Intercostal nerve block when compared with placebo also led to a shorter length of hospital stay in patients.
with rib fractures\textsuperscript{158} and those undergoing cardiac surgery.\textsuperscript{163} Compared with epidural anaesthesia, intercostal nerve block provided no benefit regarding pulmonary complications, length of hospital stay, or in-hospital death.\textsuperscript{166}

**Summary statement.** Intercostal nerve blockade provides good pain therapy for rib fractures, thoracic surgery, and laparoscopic procedures. The effects on pulmonary function after thoracotomy are comparable with those of thoracic epidural anaesthesia.

**Ilioinguinal or iliohypogastric**

Eight of 103 articles report outcome data for ilioinguinal or iliohypogastric blocks with a total of 554 patients. Five studies compared ilioinguinal or iliohypogastric blockade with placebo, one with local infiltration, one with spinal anaesthesia and one was a comparative study.

**Effectiveness.** Compared with local infiltration or placebo for hernia repair, ilioinguinal and iliohypogastric nerve blocks produced a statistically significant and clinically relevant reduction in intraoperative\textsuperscript{167} and postoperative pain in the PACU during mobilization and at rest.\textsuperscript{168} However, one study showed reduced pain scores at rest and 3 h after the procedure but similar dynamic pain scores and opioid consumption.\textsuperscript{169} Severe persistent inguinal post-herniorrhaphy pain was not reduced by ultrasound-guided lidocaine blocks of the ilioinguinal and iliohypogastric nerves at the level of the anterior superior iliac spine: the blocks were also shown to be of no value for diagnostic purposes.\textsuperscript{170} Ilioinguinal and iliohypogastric blocks significantly reduced postoperative pain and opioid consumption after renal transplantation.\textsuperscript{171} There are only two published indications for this kind of block for gynaecological surgical procedures. After bilateral ilioinguinal nerve block for hysterectomy, total morphine consumption during the first 2 postoperative days was decreased by 51\% compared with placebo, but there were no significant differences in morphine side effects between the groups.\textsuperscript{172} After inpatient surgery of the female reproductive tract, iliohypogastric–ilioinguinal nerve block did not significantly influence the utilization of postoperative opioids and did not lead to reduced pain scores.\textsuperscript{173}

**Functional recovery.** In a retrospective analysis, iliohypogastric–ilioinguinal nerve block for patients undergoing herniorrhaphy was associated with an earlier oral intake post-surgery and no need for recovery room care when compared with spinal anaesthesia.\textsuperscript{174}

**Complications.** Despite the fact that the target structures are in close relationship with sensitive anatomical structures (e.g. peritoneum), there are insufficient data to evaluate the risk – benefit relation for this nerve block. Only one case report with a massive retroperitoneal haematoma after ilioinguinal nerve block for inguinal hernia repair as a severe complication has been published.\textsuperscript{175}

**Nice to know.** For patients after hernia repair, the use of ilioinguinal and iliohypogastric nerve blocks led to an earlier hospital discharge [median 18 h (range 14–26) vs 23 (17–26), \(P=0.007\)]\textsuperscript{169} mean 14.1 h (SD 1.5) vs 42.8 (5.3), \(P<0.001\)].\textsuperscript{174} These findings, combined with improved functional recovery, suggest that this block is a cost-effective intervention for patients undergoing hernia repair.\textsuperscript{174} These findings were not reproduced in female patients undergoing surgery of the reproductive tract.\textsuperscript{173}

Blockade of the ilioinguinal and iliohypogastric nerves appears to have a more marginal effect on pain in adults than in children. It is possible that the precision of local anaesthetic placement becomes less accurate with increasing body mass index. Ultrasound, with its advantage of direct visualization of needle tip, nerve, and distribution of local anaesthetic, could improve the incidence of misplacement of the injection into the muscle layers, or even worse, into the peritoneum. This hypothesis is supported by a study using laparoscopic guidance for ilioinguinal nerve block for hernia repair. Median verbal pain scores at rest and movement were zero without any side effects.\textsuperscript{176}

**Summary statement.** Ilioinguinal–iliohypogastric nerve block provides reduced pain levels for various indications and earlier hospital discharge after hernia repair as compared with general anaesthesia alone.

**Transversus abdominis plane block**

Sixteen RCTs from 83 articles presenting outcome data from transverse abdominal plane (TAP) blocks with a total of 875 patients were identified as suitable for this review. Eleven studies compared TAP blockade with placebo, 2 with wound infiltration, 2 with epidural anaesthesia, and 1 with patient-controlled morphine administration. Success rates could not be evaluated.

**Effectiveness.** For major abdominal surgery, TAP block was equally effective with regard to pain scores, total opioid requirement, and Likert satisfaction scores as epidural anaesthesia.\textsuperscript{177} Compared with placebo, bilateral TAP blocks reduce pain scores at all postoperative time points, with reduced morphine requirements and high patient satisfaction.\textsuperscript{178} To provide analgesia for the supraumbilical abdomen after radical gastrectomy, single-injection subcostal TAP block was more effective than intravenous opioid analgesia, while continuous thoracic epidural analgesia was more effective than the single-injection subcostal TAP block.\textsuperscript{179} For laparoscopic cholecystectomy, only marginal effects on dynamic pain were shown when compared with placebo\textsuperscript{180} or local infiltration at the trocar site.\textsuperscript{181} Patients undergoing outpatient laparoscopic surgery benefited from TAP block, since it reduced pain and decreased opioid consumption [oral morphine equivalent in 24 h 39 mg (range 25–58) vs 78 mg (range 61–90)].\textsuperscript{182} Also, in patients scheduled for colorectal surgery\textsuperscript{183} and open appendectomy,\textsuperscript{184} TAP block provided effective postoperative analgesia with lower pain scores and reduced postoperative morphine consumption. For patients after radical prostatectomy, TAP block provided similar outcomes compared with wound infiltration or placebo.\textsuperscript{185} TAP block was shown to be superior in reducing...
postoperative pain and early morphine requirements in laparoscopic live-donor nephrectomy, but could not reduce morphine requirements after renal transplantation.

Furthermore, TAP block did not improve pain scores following laparoscopic hysterectomy, nor did it decrease the use of pain medication. In contrast, for open hysterectomy, TAP block led to reduced postoperative pain scores, reduced opioid consumption within the first 48 h after surgery, and less sedation. In adult female patients undergoing midline laparotomy for gynaecological malignancy, no significant difference in postoperative morphine consumption, incidence of opioid side effects, or patient satisfaction could be shown.

Functional recovery. TAP block did not improve postoperative quality of recovery (QoR-40) for patients undergoing total laparoscopic hysterectomy. In contrast, the use of TAP block in patients undergoing more minor gynaecological laparoscopic surgery led to faster readiness for discharge and was associated with a better quality of recovery. Similar results were shown for patients undergoing abdominoplasty.

Complications. In bilateral TAP block, no complications were reported for patients undergoing large bowel resection via a midline abdominal incision. Also, no adverse events occurred after TAP block for open hysterectomy, colorectal surgery, or open appendectomy.

Nice to know. There are five systematic reviews dealing with TAP blocks for abdominal surgery, caesarean section, and hysterectomy. For all these outcome data it is important to consider the technique used for the block, in particular the need for local anaesthetic to be injected into all parts of the TAP compartment. Furthermore, concerns have been discussed about local anaesthetic resorption between the muscle layers and the toxicity of ropivacaine. Ultrasound-guided bilateral dual TAP blocks did not result in clinically relevant or statistically significant changes in pulmonary function in healthy male subjects.

Summary statement. The current literature regarding TAP blockade is controversial and shows heterogeneous results regarding pain therapy. Rectus sheath blockade

Two publications out of 12 report outcome data for rectus sheath block with a total of 189 patients. No data for success rates or functional recovery are available.

Effectiveness. Bilateral rectus sheath block decreased postlaparoscopic pain in gynaecological surgery at 6 and 10 h when compared with intraperitoneal and intra-incisional infiltration of local anaesthetic. In a retrospective case note review of 98 consecutive patients undergoing major gynaecological surgery, patients who received a surgical rectus sheath block had lower pain scores on walking, required less morphine postoperatively, and had their patient-controlled analgesia discontinued earlier than patients receiving standard subcutaneous local anaesthetic applied into the wound.

Complications. Rectus sheath blocks showed slower absorption kinetics for ropivacaine than other compartment blocks.

Nice to know. Compared with local wound infiltration, patients undergoing major gynaecological surgery with rectus sheath blocks had a shortened length of hospital stay [4 days postoperatively (range 3–4) vs 5 (4–8), P < 0.001].

Summary statement. Rectus sheath blockade provides effective pain therapy after gynaecological surgery and shortened length of hospital stay.

Discussion

The most striking finding of this review is the relative lack of high quality recent outcome data for peripheral regional anaesthesia. This is especially the case for outcomes that have a longer-term impact on the patient’s health, such as functional improvement from the intended surgery or chronic pain associated with surgery. There has also been much recent interest in the role of regional anaesthesia (or avoidance of general anaesthesia and opioids) in reducing recurrence rates and patient survival following cancer surgery. We did not identify any prospective interventional study of peripheral regional anaesthesia designed to investigate such possibilities. The potential for improved functional outcome is founded on the hypothesis that early postsurgical mobilization is beneficial for longer-term benefit. Regional anaesthesia could aid early mobilization by improving dynamic pain control or prevent it by prolonged motor block. Total hip or total knee arthroplasty are examples of procedures where surgeons are requesting that their patients mobilize early, to the extent that some do not wish their patients to have a regional anaesthetic technique but prefer multimodal analgesic regimens that include wound infiltration. We conclude, however, that there is good evidence that femoral block for knee surgery, for example, provides better analgesia than wound infiltration. The overall impact on mobilization and eventual knee joint function have not been determined, and no studies have been designed to determine the optimal type and dose of local anaesthetic to balance the duration of analgesia and duration of immobility. It might be, in this instance of knee surgery, that the purely sensory block provided by saphenous nerve block is the ideal solution.

While lower limb peripheral regional anaesthesia techniques have short-term advantages over placebo or wound infiltration when combined with general anaesthesia, there are either no or only marginal benefits when compared with or added to neuraxial anaesthesia/analgesia. It was interesting that the incidence of permanent or major complications of the peripheral regional anaesthetic techniques we reviewed appears to be very low, especially when compared with the incidence of death or permanent neurological damage following neuraxial anaesthesia. This would suggest that the role of neuraxial anaesthesia for procedures on the lower limb should be restricted to providing an alternative to general anaesthesia (when this is not feasible with peripheral blocks),
when the risks of general anaesthesia are considered to be greater for the patient, or if the patient has an informed preference for regional anaesthesia. When a regional anaesthetic technique is required for lower limb analgesia, peripheral regional techniques appear to be safer than neuraxial analgesia.

For upper limb surgery, there is evidence that postoperative analgesia is improved by using an appropriate brachial plexus block other than the supraclavicular block, where a lack of data prevent any conclusion. Full health economic analyses of brachial plexus blocks have not been done, but these blocks reproducibly improve the patient pathway, suggesting an efficiency and economic benefit. This applies when brachial plexus techniques are combined with general anaesthesia as well as when they form the sole anaesthesia technique. Complications are likely to be reduced by applying an evidence-based approach to minimize local anaesthetic dosing, which is most easily achieved when ultrasound-guided techniques are used. Comparative trials, which have been the focus of this review, are not the best tool to estimate the incidence of rare events. The albeit limited data of serious sequelae from peripheral regional anaesthesia techniques suggest that accurate estimates will benefit from a similar approach to that used to estimate major complications of neuraxial blocks.1

For blocks of the trunk, short-term benefits (improved pain relief, greater patient satisfaction, and/or earlier hospital discharge) have been demonstrated for those that we reviewed other than the TAP block, where data are conflicting. It is difficult to know whether the different outcomes for TAP block reflect comparative technical success rates for correct placement of the local anaesthetic or whether the block does not provide adequate coverage for the procedures investigated. Cervical plexus blocks are associated with high patient satisfaction, but local anaesthesia (including cervical plexus blocks) was not associated with a reduced incidence of major adverse outcomes (death or stroke) following carotid endarterectomy.150 For the other blocks of the trunk there were no studies that investigated relevant longer-term outcomes, for example, the effect of intercostal blocks on chronic post-thoracotomy or post-mastectomy pain.

In conclusion, improved patient comfort and/or satisfaction have been demonstrated with the majority of the peripheral regional anaesthetic blocks that we have covered in this review. Very few additional patient benefits have evidential support. The incidence of transient neurological symptoms related to blocks is variable but generally not uncommon. Our review is unable to provide an accurate estimate of permanent nerve damage because this complication is rare. Future studies in the field of peripheral regional anaesthesia should focus on functional outcomes. Considerations regarding well-performed regional anaesthetic techniques and improved functional outcome are appealing and would raise our speciality to a higher level.

Authors’ contributions
The authors contributed equally to the conception and design of the article, analysis, interpretation of the data, and drafting of the manuscript.

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