# Regional Anaesthesia: What matters?


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### Training and Education

Training in regional anaesthesia is often conducted in an ad-hoc manner related to the availability of both surgical cases appropriate for regional anaesthesia and individuals with appropriate expertise in the field. Many studies on training in regional anaesthesia have focused on a minimum number of procedures required to achieve competency. In many training scenarios, the recommended number of cases is simply not available. An alternative approach is to structure training so that it follows valid educational principles that are relevant to motor skills training in regional anaesthesia.[1]

A. **Creating the pre-trained novice:** Ultrasound-guided nerve block procedures comprise discreet component tasks that when deconstructed provide a basis for teaching, learning and assessment of skills. In the motor skill learning literature, fractionization refers to practising a discreet component of a complex motor skill separately.[2] Acquiring relevant sonograms and identifying anatomical structures is a discreet component skill required for ultrasound-guided regional anaesthesia. A second key component skill is needle-guidance under ultrasound. Both sonography and needling skills can be practiced in a non-clinical environment and then combined with other skills and knowledge to perform a clinical procedure.

   Learning motor skills in an environment remote from the operating room and clinical responsibilities has merit. As a motor skill, sonography skills required for regional anaesthesia are relatively complex requiring a high level of cognitive involvement. During an early stage of their training, trainees should become familiar with task demands and acquire and develop a degree of automaticity in the core psychomotor skills required for specific procedures before performing them on patients. When a trainee then performs the procedure in the clinical environment it then requires less attentional capacity and information processing for the core skills as these would have been developed during their prior part- task training. The trainees' attention could then be more fully committed to higher-order processes and developing key attributes including communication, team-working, planning and decision making. [3]

B. **Deliberate practice:** is required to create the pre-trained novice ready for regional anaesthesia and to further develop practitioners with wide levels of expertise. It is likely that anyone, regardless of expertise will benefit from deliberate practice. The key point is that an expert will be practicing a different task to that practiced by the novice. The validity of deliberate practice has been demonstrated in many fields including music, chess, sport and medicine. The term deliberate practice does not appear commonly in the anaesthetic literature, however in a recent edition of Anesthesia and Analgesia, there is a review article on deliberate practice.[4]

   An example of the benefits of deliberate practice is demonstrated in the following example. Ten University of Melbourne Doctor of Medicine students, all novices to ultrasound, had their sonographic proficiency assessed in a structured teaching environment. Proficiency was measured by the novices ability to acquire and interpret sonograms required for ultrasound-guided axillary brachial plexus block. Figure 1 demonstrates that within 8 – 10 supervised scanning sessions that included feedback; novice participants achieved sonographic proficiency (maximum score possible, 18) at this anatomical site.

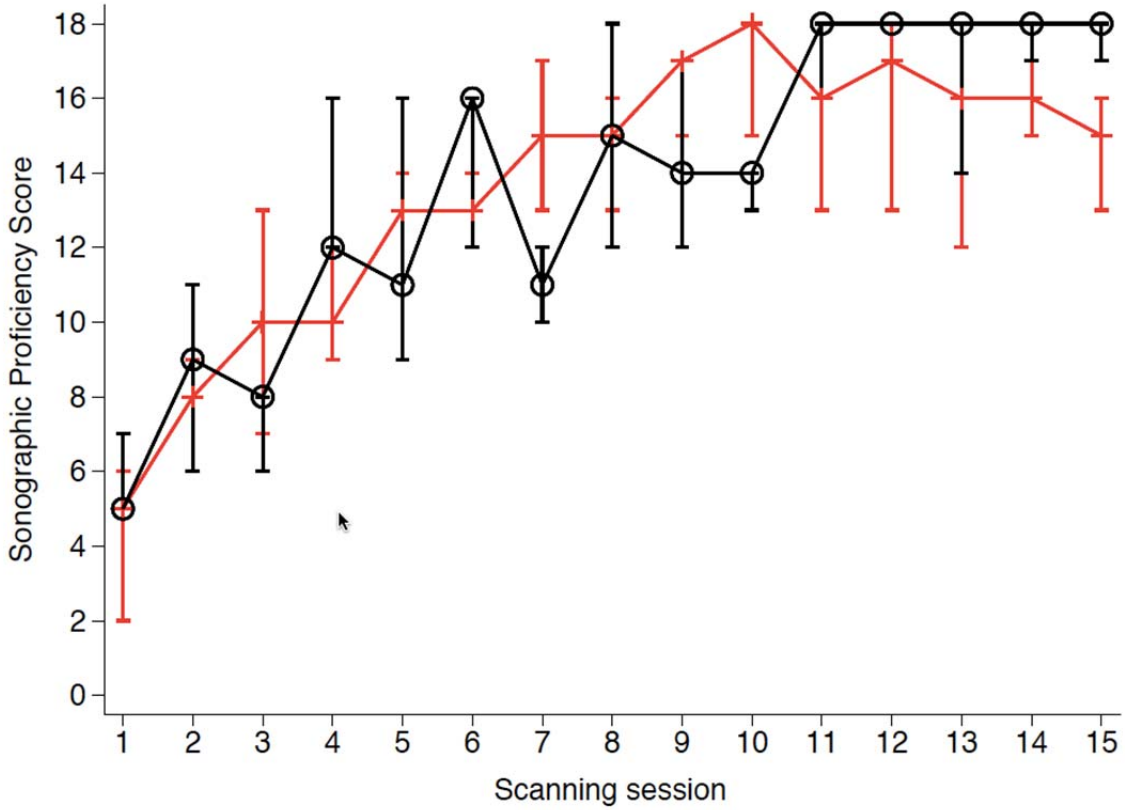


Figure 1. Group median (and interquartile range) of 'Sonographic Proficiency Scores' versus Scanning Session for massed (—+—) and distributed (—⊠—) groups.

C. **Preoperative briefing/debrief:** this can set the goals for the learning exercise (procedure) and set out the boundaries for what tasks will be done by whom. The briefing can assess the trainee's knowledge and a standard dialogue can be used. This is a dialogue that I commonly use for a registrar before performing a procedure. This assesses the trainees knowledge in advance of assessment of procedural skills required for trainee Work-based assessments.[5]

Pre-procedure interview (away from patient)

1. What is the name of the block and what is the indication for the block?
2. What are the most important anatomical landmarks?
   (Provide clues if necessary: Nerves, vessels, muscles, fascial planes if relevant)
3. What sensory and motor blockade will the block produce?
4. Assume I am the patient. Please provide me with information that I require to make an informed decision and be able to consent (or not) to this block procedure.
   (Provide clues if necessary: Side effects, risks and complications)
5. What monitoring are you going to use during the block?
6. What probe are you going to use?
   (If trainee states anything other than high or intermediate frequency/ linear probe, ask for further explanation).
7. Patient is …kg:
   What are you going to inject and what volume and concentration? What needle type?
8. Post-procedure management:

How are you going to test the success of the block?

If the block is unsuccessful (or incomplete) what are you going to do (assuming you still plan to proceed for surgery)?

If the block is successful what instructions are you going to give the patient and the nurse looking after the patient, after the operation?
The preoperative briefing can be used to discuss a wide range of logistical, generic clinical and hospital-specific issues relating to a particular case. Feedback given to a trainee when a procedure is completed can track back to learning objectives.

**D. Educational concepts to consider during and immediately following a procedure:**

a. Learning versus performance - performance of a motor skill is a measure of immediate aptitude. If a learning session leads to a sustained improvement in performance then learning has occurred. During a teaching session, improvement in a measurable aspect of a registrar's performance does not necessarily reflect learning. For learning to occur the improvement must persist or be transferrable to other skills.

b. Concurrent feedback - Feedback delivered during the performance of a skill. Concurrent feedback may be required for a novice however; if feedback is delivered during the procedure it may inhibit learning of an intermediate practitioner. In this setting concurrent feedback may represent coaching and inhibit progress towards independent practice.

c. Motor skill level of trainee - recognising the level of motor skill development is helpful in determining the required level of supervision and content of feedback. Motor skill stages have behavioral and neuropsychological correlates. Ideally the pre-trained novice has reached the intermediate stage of motor skill development. At the intermediate stage there is a degree of automaticity in the learners actions. We are more relaxed, have increased confidence and efficiency improves.

d. Zone of proximal development - When a registrar performs a task that is difficult enough that they require help from a tutor, it is described as being in the zone of proximal development. Tasks performed in this zone promote learning.

e. Scaffolding – is a term used to describe the support given to a registrar when they are performing a task in the zone of proximal development. Scaffolding also refers to support provided to control and monitor the clinical environment so that the trainee can focus on a specific skill.

f. Summary feedback – Feedback provided shortly after the procedure is completed. One method of initiating a discussion is to ask: "How do you think you performed?" Feedback should be targeted and focus on 2 -3 points including constructive feedback, positive feedback and identification of weaknesses.

## Standardized pathways and the Perioperative Surgical Home

It is essential that regional anaesthesia is integrated into the modern paradigm of perioperative care. The modern paradigm of care includes programs such as Enhanced Recovery After Surgery (ERAS) and the Perioperative Surgical Home (PSH). The American Society of Anesthesiologists has proposed the PSH as a potential solution to the variability in both the cost and quality of perioperative care in the United States.[6] There is increasing demand to demonstrate value to patients, insurers and our patients. ERAS and PSH call for standardized, evidenced-based interdisciplinary perioperative pathways for commonly performed surgical procedures. Although PSH is likely to include ERAS pathways, the conceptual framework for PSH is more encompassing than ERAS. According to Kain, the PSH is a practice model that emphasizes superior coordination of care from the minute a decision to operate is made until 30 days after discharge. PSH aims to implement evidenced-based preoperative, intraoperative and postoperative protocols with minimal variability across an institution. Protocols will vary based on surgical services and will be tailored to the local environment. PSH will leverage data as a means to evaluate and improve all interventions in a continuous manner. Opportunities exist because of the vast amounts of information being collected from existing information technology infrastructure.[7] Length of stay and other metrics relating to cost are outcome measures that the PSH aims to collect. For example, in a total joint pathway developed for the PSH, the median length of stay for both total knee and hip arthroplasties was 3 (2-3) days, median (95% confidence interval).[6] Of relevance to our

current practice is that, these results (for length of stay) were obtained without the use of regional anaesthesia techniques traditionally used by anaesthesiologists.

In many scenarios, the lack of controlled trials relevant to a clinical pathway make it difficult to definitively recommend a specific technique for a pathway and often, there are several anaesthetic and analgesic options. Therefore, we may rely on consensus statements and expert opinions. As far as possible, in the PSH all therapies that the patient are exposed to will be based on evidenced-based best practice. In addition, the goal of PSH is to minimise variability within a given institution in the perioperative therapies and interventions that patients are exposed to. The PSH therefore requires development of standardized pathways for each stage of the perioperative care for commonly performed operations.

In the table below are examples of components of a pathway for total joint arthroplasty. This structure contains content that is not meant to be definitive and in no way implies that there is consensus on many of the components of the pathway.

| Anaesthetic pathway for total joint arthroplasty |
|---|
| **Goals of the pathway**<br>The goals of the pathway should be clearly stated, and may include reduction in mortality, morbidity, and costs, increases in patient satisfaction and improved pain control. |
| **Patient selection**<br>Modifiable risk factors, such as smoking, poorly controlled diabetes, obesity, and recreational drug use may affect rates of surgical complications.[8] The pathway may address when surgery should be delayed to address these factors. Non-modifiable co-morbidities that create an unacceptable surgical risk may be included in a pathway. |
| **Preoperative education and preadmission planning**<br>This provides an opportunity to identify patient characteristics that conflict with the default elements in the anaesthetic pathway and address them preoperatively. If the pathway includes continuous peripheral nerve catheters, this may provide an opportunity for patient education. Patients should be coached on use of multimodal analgesia. Preoperative physical therapy should be considered. |
| **Pre-procedure checklist**<br>This pathway element frequently includes patient identification, site marking, confirmation of allergies, comorbidities, availability of blood products, coagulation status, and final checks of blood results. |

**Multimodal analgesia**

| Agent | Benefits | Drawbacks |
|---|---|---|
| Paracetamol | Reduce postoperative pain scores, opioids sparing.[9] | Hepatotoxicity. |
| Gabapentin / pregabalin | Reduce postoperative pain scores, opioid sparing,[10] may reduce incidence of chronic postsurgical pain [11] and benefit patients with chronic pain.[12] | Increased sedation, particularly in elderly, increased respiratory depression with doses > 300 mg (when combined with general but not neuraxial anaesthesia).[13] |
| Cyclooxygenase - 2 inhibitors | Reduce postoperative pain scores, opioids sparing.[14] | Renal impairment. |
| Oral opioids (e.g. sustained release oxycodone) | Reduce postoperative pain scores.[15] | Increased risk of respiratory depression with oxycodone dose > 10 mg (when combined with general but not neuraxial anaesthesia).[13] |

## Use of regional anaesthesia for postoperative pain control

The choice of technique may affect other elements of the pathway. Approaches are evolving as new techniques, equipment and drugs become available. The following table lists common sites used for regional anesthesia, along with benefits and drawbacks.

| Technique | Benefits | Drawbacks |
|---|---|---|
| Epidural block | Considered the gold standard for postoperative analgesia for a range of surgeries. | The side-effect profile may interfere with modern care pathway and rare risk of catastrophic outcome (e.g. epidural hematoma).[16,17] |
| Femoral nerve block | Effective for knee surgery without drawbacks of epidural;[18] associated with improved outcomes at 6 weeks in one trial.[19] | Quadriceps weakness may interfere with rehabilitation. Small risk (2 – 4 per 10,000) of long-term nerve injury [20] but overall choice of anaesthetic does change risk of nerve injury.[21] |
| Sciatic nerve block | Reduced posterior knee pain.[22] | Risk of neuropathy similar to femoral nerve block. May improve analgesia and early mobilization [23] or add little analgesia to existing femoral block. [24,25], unlikely to improve long-term outcomes.[26] |
| Selective tibial nerve block | Reduced likelihood of foot drop.[27] | Injection close to popliteal crease, risk of peroneal nerve injury with lateral to medial approach or vascular injury. |
| Adductor canal | Similar (but probably not as effective) pain relief to femoral nerve block with reduced muscle weakness,[28,29] effective in treating existing severe pain.[30] | Closer to surgical site, evolving technique. |
| Local infiltration analgesia | Easy and quick to perform, no muscle weakness. | Evolving evidence for efficacy.[31] However, experts point to poor quality of some of the existing studies.[32] Success of technique, likely operator-dependent. Associated with transient peroneal nerve palsy.[33] |

Other variables to consider for regional anaesthesia.

| Technique | Benefits | Drawbacks |
|---|---|---|
| Single shot | Quick to perform, low cost, effective.[18] | Shortest duration (may be benefit if rapid recovery of muscle strength is required for physical therapy). |
| Nerve catheter | Improved analgesia compared to single –injection technique.[34] Longest duration of analgesia, relatively titratable. | More difficult and time consuming to perform, more expensive, requires postoperative surveillance. |
| Extended release formulations of local anaesthetic (e.g. liposomal bupivacaine) | As quick to perform as single shot block, with longer block duration | Compared with bupivacaine, currently little evidence of efficacy [35]. Costly. Limits ability to redo block. Safety and side-effect profile currently emerging.[36] |

## Surgical anaesthesia

Options for surgical anesthesia are summarized in the table below.

| Anaesthesia | Benefits | Drawbacks |
|---|---|---|
| Spinal | Associated with improved outcomes including a mortality benefit in some[37,38] but not all studies.[39] | Technically difficult on certain patients. Rare catastrophic outcomes. Duration of spinal anaesthesia may be inadequate for surgery. Patients may be reluctant to be 'awake' for surgery. |
| Epidural | Similar benefits as spinal, but can be used for postoperative analgesia and longer duration surgeries. | Can be technically difficult on certain patients. Rare catastrophic outcomes, e.g. epidural hematoma.[16,17]. Patients may be reluctant to be 'awake' for surgery. |
| General | Complete amnesia | Rare catastrophic outcome (e.g. difficult airway), increased risk of respiratory depression.[13] |

Neuraxial anaesthesia is associated with improved outcomes [37,40] however this modality is not always preferred.[41] If neuraxial anaesthesia is employed, decisions regarding the inclusion or exclusion of long- or short- acting opioids are relevant as it may impact on subsequent pathway elements (postoperative monitoring, rehabilitation, etc.). Even patients who receive neuraxial anaesthesia usually require sedation and some pathways may specify the desired level of sedation.

## Intraoperative drugs

This may include first- and second-line antibiotics, preferred antiemetics for spinal anaesthesia versus general anaesthesia, and preferred sedatives for spinal or epidural anaesthesia. Anticoagulation is usually started in the postoperative period by the surgery team, but may be commented upon here. Intraoperative dexamethasone appears to improve postoperative pain scores as well as proving an effective antiemetic.[42]

## Intraoperative transfusion goals and blood conservation options

Blood transfusion has risks[43] and one of the goals of the pathway may be to minimize blood loss and hence transfusion requirements. A wide variety of techniques are available to minimize blood loss, some of which are summarized in the table below.

| Technique | Benefits | Drawbacks |
|---|---|---|
| Intraoperative hypotension | Reduced blood loss | Increased vigilance and monitoring required. Risk of end-organ ischaemia. Under-resuscitation may contribute to postoperative orthostatic intolerance impairing early mobilisation |
| Tourniquet use | Reduced blood loss and protocols exist on appropriate use. [44] | Risk of ischaemic injury or axonal neuropathy [45-47] or effect on quadriceps function. [48] |
| Appropriate thermoregulation | Reduced blood loss via maintenance of coagulation cascade, improved recovery | |
| Cell scavenging | Reduced exposure to allogenic blood products | Added cost and complexity |
| Reinfusion drains | Reduced allogenic blood product requirements | Added cost and complexity |
| Tranexamic acid | Reduced blood loss due to antifibrinolysis. [49] | Association with seizures.[50] No known increased risk of thrombotic events but has only recently come into use in this surgical population. |

## Postoperative pain control

Pathways often address pain control for patients with chronic pain or opioid use, as well as those without. Generally this section will comment on both the expected infusion regimens for continuous peripheral nerve blockade,[51] as well as adjuvants such as patient control opioid administration, ketamine, or other drugs.

### Considerations regarding orthopedic surgical pathway

Anaesthetic pathways need to comment upon ways in which they interact with the surgeon's pathway, and make it clear why particular recommendations are made.

### What outcomes matter

Likely our sub-specialty will need to focus on long-term, more definitive and patient-centred outcomes including: 30-day mortality,[37] disability free survival,[52] validated Quality of Recovery Scores,[53] robust measures of postoperative pain such as the Brief Pain Inventory,[54] hospital length of stay, re-admission rates and persistent post-surgical pain.[55,56]

### Having a broader perspective

Patient outcomes may benefit from anaesthetists' having a broader perspective, collaborating outside of their specialty, incorporating a diverse set of viewpoints, backgrounds and skills. Vincent has eloquently outlined the benefits of multidisciplinary work, collaboration and exchange.[57] Dr Neuman (USA) has been awarded the 2015 American Society of Anesthesiology Presidential Scholar award.[58] Recently, he also received $11.9 million funding from the Patient Centered Outcomes Research Institute for a major, multicenter pragmatic trial of spinal versus general anaesthesia for patients having surgery for fractured neck of femur. This proposal required engagement with a wide array of patients and stakeholders, including local elder advocacy organizations, the American Society of Anesthesiology and the Anesthesia Quality Institute, the U.S. Centers for Medicare and Medicaid Services, other organisations and professional societies; as well as 37 academic and community hospitals in the United States, Canada, and Australia.[58]

## References


1. Slater RJ, Castanelli DJ, Barrington MJ: Learning and teaching motor skills in regional anesthesia: a different perspective. *Reg Anesth Pain Med* 2014; 39: 230-239
2. Schmidt R. Supplementing the Learning Experience In. In: *Motor Learning and Performance - A Situation-Based Learning Approach 4th Edition.* 4th edn. Champaign, IL, USA: Human Kinetics; 2008: 218 - 253.
3. Fletcher GC, McGeorge P, Flin RH, Glavin RJ, Maran NJ: The role of non-technical skills in anaesthesia: a review of current literature. *Br J Anaesth* 2002; 88: 418-429
4. Hastings RH, Rickard TC: Deliberate practice for achieving and maintaining expertise in anesthesiology. *Anesth Analg* 2015; 120: 449-459
5. Watson MJ, Wong DM, Kluger R, et al.: Psychometric evaluation of a direct observation of procedural skills assessment tool for ultrasound-guided regional anaesthesia. *Anaesthesia* 2014; 69: 604-612
6. Garson L, Schwarzkopf R, Vakharia S, et al.: Implementation of a total joint replacement-focused perioperative surgical home: a management case report. *Anesth Analg* 2014; 118: 1081-1089
7. Cyriac J, Cannesson M, Kain Z: Pain management and the perioperative surgical home: getting the desired outcome right. *Reg Anesth Pain Med* 2015; 40: 1-2
8. Peersman G, Laskin R, Davis J, Peterson M: Infection in total knee replacement: a retrospective review of 6489 total knee replacements. *Clin Orthop Relat Res* 2001: 15-23
9. Zhou TJ, Tang J, White PF: Propacetamol versus ketorolac for treatment of acute postoperative pain after total hip or knee replacement. *Anesth Analg* 2001; 92: 1569-1575
10. Mishriky BM, Waldron NH, Habib AS: Impact of pregabalin on acute and persistent postoperative pain: a systematic review and meta-analysis. *Br J Anaesth* 2015; 114: 10-31
11. Clarke H, Bonin RP, Orser BA, Englesakis M, Wijeysundera DN, Katz J: The prevention of chronic postsurgical pain using gabapentin and pregabalin: a combined systematic review and meta-analysis. *Anesth Analg* 2012; 115: 428-442
12. Sawan H, Chen AF, Viscusi ER, Parvizi J, Hozack WJ: Pregabalin reduces opioid consumption and improves outcome in chronic pain patients undergoing total knee arthroplasty. *Phys Sportsmed* 2014; 42: 10-18
13. Weingarten TN, Jacob AK, Njathi CW, Wilson GA, Sprung J: Multimodal Analgesic Protocol and Postanesthesia Respiratory Depression During Phase I Recovery After Total Joint Arthroplasty. *Reg Anesth Pain Med* 2015; 40: 330-336
14. Lin J, Zhang L, Yang H: Perioperative administration of selective cyclooxygenase-2 inhibitors for postoperative pain management in patients after total knee arthroplasty. *J Arthroplasty* 2013; 28: 207-213 e202
15. Rothwell MP, Pearson D, Hunter JD, et al.: Oral oxycodone offers equivalent analgesia to intravenous patient-controlled analgesia after total hip replacement: a randomized, single-centre, non-blinded, non-inferiority study. *Br J Anaesth* 2011; 106: 865-872
16. Pumberger M, Memtsoudis SG, Stundner O, et al.: An analysis of the safety of epidural and spinal neuraxial anesthesia in more than 100,000 consecutive major lower extremity joint replacements. *Reg Anesth Pain Med* 2013; 38: 515-519
17. Bateman BT, Mhyre JM, Ehrenfeld J, et al.: The risk and outcomes of epidural hematomas after perioperative and obstetric epidural catheterization: a report from the Multicenter Perioperative Outcomes Group Research Consortium. *Anesth Analg* 2013; 116: 1380-1385
18. Paul JE, Arya A, Hurlburt L, et al.: Femoral nerve block improves analgesia outcomes after total knee arthroplasty: a meta-analysis of randomized controlled trials. *Anesthesiology* 2010; 113: 1144-1162
19. Carli F, Clemente A, Asenjo JF, et al.: Analgesia and functional outcome after total knee arthroplasty: periarticular infiltration vs continuous femoral nerve block. *Br J Anaesth* 2010; 105: 185-195
20. Neal JM, Barrington MJ, Brull R, et al.: The Second ASRA Practice Advisory on Neurologic Complications Associated With RegionalAnesthesia and Pain Medicine Executive Summary 2015. *Reg Anesth Pain Med* 2015; Volume 40, Number 5, September-October 2015
21. Jacob AK, Mantilla CB, Sviggum HP, Schroeder DR, Pagnano MW, Hebl JR: Perioperative nerve injury after total knee arthroplasty: regional anesthesia risk during a 20-year cohort study. *Anesthesiology* 2011; 114: 311-317

22. Sato K, Adachi T, Shirai N, Naoi N: Continuous versus single-injection sciatic nerve block added to continuous femoral nerve block for analgesia after total knee arthroplasty: a prospective, randomized, double-blind study. *Reg Anesth Pain Med* 2014; 39: 225-229
23. Cappelleri G, Ghisi D, Fanelli A, Albertin A, Somalvico F, Aldegheri G: Does continuous sciatic nerve block improve postoperative analgesia and early rehabilitation after total knee arthroplasty? A prospective, randomized, double-blinded study. *Reg Anesth Pain Med* 2011; 36: 489-492
24. Abdallah FW, Chan VW, Gandhi R, Koshkin A, Abbas S, Brull R: The analgesic effects of proximal, distal, or no sciatic nerve block on posterior knee pain after total knee arthroplasty: a double-blind placebo-controlled randomized trial. *Anesthesiology* 2014; 121: 1302-1310
25. Safa B, Gollish J, Haslam L, McCartney CJ: Comparing the effects of single shot sciatic nerve block versus posterior capsule local anesthetic infiltration on analgesia and functional outcome after total knee arthroplasty: a prospective, randomized, double-blinded, controlled trial. *J Arthroplasty* 2014; 29: 1149-1153
26. Wegener JT, van Ooij B, van Dijk CN, et al.: Long-term pain and functional disability after total knee arthroplasty with and without single-injection or continuous sciatic nerve block in addition to continuous femoral nerve block: a prospective, 1-year follow-up of a randomized controlled trial. *Reg Anesth Pain Med* 2013; 38: 58-63
27. Sinha SK, Abrams JH, Arumugam S, et al.: Femoral nerve block with selective tibial nerve block provides effective analgesia without foot drop after total knee arthroplasty: a prospective, randomized, observer-blinded study. *Anesth Analg* 2012; 115: 202-206
28. Jaeger P, Zaric D, Fomsgaard JS, et al.: Adductor canal block versus femoral nerve block for analgesia after total knee arthroplasty: a randomized, double-blind study. *Reg Anesth Pain Med* 2013; 38: 526-532
29. Kwofie MK, Shastri UD, Gadsden JC, et al.: The effects of ultrasound-guided adductor canal block versus femoral nerve block on quadriceps strength and fall risk: a blinded, randomized trial of volunteers. *Reg Anesth Pain Med* 2013; 38: 321-325
30. Jaeger P, Grevstad U, Henningsen MH, Gottschau B, Mathiesen O, Dahl JB: Effect of adductor-canal-blockade on established, severe post-operative pain after total knee arthroplasty: a randomised study. *Acta Anaesthesiol Scand* 2012; 56: 1013-1019
31. den Hartog YM, Mathijssen NM, van Dasselaar NT, Langendijk PN, Vehmeijer SB: No effect of the infiltration of local anaesthetic for total hip arthroplasty using an anterior approach: A randomised placebo controlled trial. *Bone Joint J* 2015; 97-B: 734-740
32. Andersen LO, Kehlet H: Analgesic efficacy of local infiltration analgesia in hip and knee arthroplasty: a systematic review. *Br J Anaesth* 2014; 113: 360-374
33. Tsukada S, Wakui M, Hoshino A: Postoperative epidural analgesia compared with intraoperative periarticular injection for pain control following total knee arthroplasty under spinal anesthesia: a randomized controlled trial. *J Bone Joint Surg Am* 2014; 96: 1433-1438
34. Bingham AE, Fu R, Horn JL, Abrahams MS: Continuous peripheral nerve block compared with single-injection peripheral nerve block: a systematic review and meta-analysis of randomized controlled trials. *Reg Anesth Pain Med* 2012; 37: 583-594
35. Schroer WC, Diesfeld PG, LeMarr AR, Morton DJ, Reedy ME: Does Extended-Release Liposomal Bupivacaine Better Control Pain Than Bupivacaine After TKA? A Prospective, Randomized Clinical Trial. *J Arthroplasty* 2015
36. Ilfeld BM, Viscusi ER, Hadzic A, et al.: Safety and Side Effect Profile of Liposome Bupivacaine (Exparel) in Peripheral Nerve Blocks. *Reg Anesth Pain Med* 2015
37. Memtsoudis SG, Sun X, Chiu YL, et al.: Perioperative comparative effectiveness of anesthetic technique in orthopedic patients. *Anesthesiology* 2013; 118: 1046-1058
38. Memtsoudis SG, Sun X, Chiu YL, et al.: Utilization of critical care services among patients undergoing total hip and knee arthroplasty: epidemiology and risk factors. *Anesthesiology* 2012; 117: 107-116
39. Neuman MD, Rosenbaum PR, Ludwig JM, Zubizarreta JR, Silber JH: Anesthesia technique, mortality, and length of stay after hip fracture surgery. *JAMA* 2014; 311: 2508-2517
40. Pugely AJ, Martin CT, Gao Y, Mendoza-Lattes S, Callaghan JJ: Differences in short-term complications between spinal and general anesthesia for primary total knee arthroplasty. *J Bone Joint Surg Am* 2013; 95: 193-199
41. Fleischut PM, Eskreis-Winkler JM, Gaber-Baylis LK, et al.: Variability in anesthetic care for total knee arthroplasty: an analysis from the anesthesia quality institute. *Am J Med Qual* 2015; 30: 172-179

42. Backes JR, Bentley JC, Politi JR, Chambers BT: Dexamethasone reduces length of hospitalization and improves postoperative pain and nausea after total joint arthroplasty: a prospective, randomized controlled trial. *J Arthroplasty* 2013; 28: 11-17
43. Goodnough LT: Risks of blood transfusion. *Crit Care Med* 2003; 31: S678-686
44. Fitzgibbons PG, Digiovanni C, Hares S, Akelman E: Safe tourniquet use: a review of the evidence. *J Am Acad Orthop Surg* 2012; 20: 310-319
45. Nitz AJ, Dobner JJ, Matulionis DH: Pneumatic tourniquet application and nerve integrity: motor function and electrophysiology. *Exp Neurol* 1986; 94: 264-279
46. Kornbluth ID, Freedman MK, Sher L, Frederick RW: Femoral, saphenous nerve palsy after tourniquet use: a case report. *Arch Phys Med Rehabil* 2003; 84: 909-911
47. Weingarden SI, Louis DL, Waylonis GW: Electromyographic changes in postmeniscectomy patients. Role of the pneumatic tourniquet. *JAMA* 1979; 241: 1248-1250
48. Saunders KC, Louis DL, Weingarden SI, Waylonis GW: Effect of tourniquet time on postoperative quadriceps function. *Clin Orthop Relat Res* 1979: 194-199
49. Kagoma YK, Crowther MA, Douketis J, Bhandari M, Eikelboom J, Lim W: Use of antifibrinolytic therapy to reduce transfusion in patients undergoing orthopedic surgery: a systematic review of randomized trials. *Thromb Res* 2009; 123: 687-696
50. Murkin JM, Falter F, Granton J, Young B, Burt C, Chu M: High-dose tranexamic Acid is associated with nonischemic clinical seizures in cardiac surgical patients. *Anesth Analg* 2010; 110: 350-353
51. Ilfeld BM, Moeller LK, Mariano ER, et al.: Continuous peripheral nerve blocks: is local anesthetic dose the only factor, or do concentration and volume influence infusion effects as well? *Anesthesiology* 2010; 112: 347-354
52. Shulman MA, Myles PS, Chan MT, McIlroy DR, Wallace S, Ponsford J: Measurement of disability-free survival after surgery. *Anesthesiology* 2015; 122: 524-536
53. Stark PA, Myles PS, Burke JA: Development and psychometric evaluation of a postoperative quality of recovery score: the QoR-15. *Anesthesiology* 2013; 118: 1332-1340
54. Ilfeld BM, Madison SJ, Suresh PJ, et al.: Treatment of postmastectomy pain with ambulatory continuous paravertebral nerve blocks: a randomized, triple-masked, placebo-controlled study. *Reg Anesth Pain Med* 2014; 39: 89-96
55. Karmakar MK, Samy W, Li JW, et al.: Thoracic paravertebral block and its effects on chronic pain and health-related quality of life after modified radical mastectomy. *Reg Anesth Pain Med* 2014; 39: 289-298
56. Ilfeld BM, Madison SJ, Suresh PJ, et al.: Persistent postmastectomy pain and pain-related physical and emotional functioning with and without a continuous paravertebral nerve block: a prospective 1-year follow-up assessment of a randomized, triple-masked, placebo-controlled study. *Ann Surg Oncol* 2015; 22: 2017-2025
57. Vincent C, Batalden P, Davidoff F: Multidisciplinary centres for safety and quality improvement: learning from climate change science. *BMJ Qual Saf* 2011; 20 Suppl 1: i73-78
58. Fleisher LA: Mark D. Neuman, M.D., M.Sc., Recipient of the 2015 Presidential Scholar Award. *Anesthesiology*; 123