



Rapid recovery following hip and knee arthroplasty using local infiltration analgesia: length of stay, rehabilitation protocol and cost savings

Islam Nassar ,* Julie Fahey† and David Mitchell*

*Ballarat Health Services (Ballarat Base Hospital), St John of God Hospital, Ballarat, Victoria, Australia and

†Ballarat OSM, Ballarat, Victoria, Australia

Key words

economics of hip or knee arthroplasty, fast track total hip or knee replacement, inpatient rehabilitation after joint replacement, local infiltration analgesia, rapid recovery hip or knee arthroplasty.

Correspondence

Dr Islam Nassar, Orthopaedic Department, Gosford Hospital, Central Coast Local Health District, Holden Street, Gosford, NSW 2250, Australia. Email: drnassarislam@gmail.com

I. Nassar MBBCh, MCh (Orth), MBA/MHA; **J. Fahey** RN, PONC, GDip (Periop), MNurs (Health Science); **D. Mitchell** MBBS, FRACS (Orth).

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

Accepted for publication 16 December 2019.

doi: 10.1111/ans.15663

Introduction

Local infiltration analgesia (LIA) was introduced to help overcome historical problems of lower limb joint replacements being associated with significant postoperative pain and residual dissatisfaction; a recent large series of 1703 primary total knee replacements found that 19% of patients were dissatisfied with their outcome.¹ Similarly, in a systematic review, approximately 20% of patients reported moderate to severe knee or hip pain following joint surgery.² Acute post-operative pain hinders the rapid recovery and rehabilitation process, and the severity of acute postoperative pain is considered a contributing factor for chronic pain after hip or knee arthroplasty.³ To manage pain after total hip replacement (THR) and total knee arthroplasty (TKA), several pain management methods such as patient-controlled

Abstract

Background: We implemented local infiltration analgesia (LIA) as a technique of providing post-operative pain management and early mobilization after arthroplasty surgery and have progressively found patients able to go home earlier. This study compares the national data on hip and knee arthroplasty provided by the Royal Australasian College of Surgeons and Medibank Private with our outcomes using LIA and rapid recovery.

Methods: Prospective study of one surgeon including 200 knees, and 165 hips in the two years till June 2016. Variables included in comparison to the two groups were: length of stay, percentage of patients transferred to rehabilitation or intensive care unit (ICU), readmitted within 30 days and average separation cost.

Results: Hip replacement median length of stay in our series was two nights versus five nights, inpatient rehabilitation 7% versus 36%, ICU admission zero versus 4%, and readmissions 3.9% versus 6.0%, the average hospital separation cost in our series was \$17 813 versus \$26 734. Knee replacement median length of stay in our study was one night versus five nights, ICU 0.5% versus 3%, rehabilitation 4.5% versus 43%, and readmission 6% versus 7%, the average hospital separation cost in our group was \$16 437 versus \$27 505.

Conclusion: The comprehensive approach of LIA and rapid recovery enables patients to have shorter hospitalization, lower rehabilitation incidence and a resultant reduction in health expenditure.

analgesia, narcotics, epidural analgesia and peripheral nerve block have emerged.⁴ However, each of these methods is associated with their own specific problems, which hinder early mobilization.^{5–10} The use of conventional pain management protocols after joint replacements may contribute to a higher incidence of structured inpatient rehabilitation programs in Australia.¹¹

Rapid recovery principles are now well established. These include pre-operative counselling of the patient, minimal pre-operative fasting, pre-operative carbohydrate oral loading, minimizing general anaesthetic agents and narcotics, preference for axial and more peripheral nerve blocks and LIA, avoidance of intravenous fluids, active intra-operative warming of the patient, multi-modal analgesia, aggressively managing nausea, early mobilization, and early discharge.¹²

LIA is a key component of a comfortable, ambulant, independent patient, not troubled by nausea of narcotics. Taken to its extreme, through the use of a wound catheter, it is possible to keep the region anaesthetised for 36 h, reduced the inflammation caused by the surgery, dampening the 'inflammatory biological soup',¹³ and reduce the physiological impact of the surgery to that similar to a sporting injury. Independent publications confirm LIA improves post-operative pain through decreasing inflammation process and swelling in post-operative TKA patients as a result of lowering serum C-reactive protein concentration, and surgical wound drainage fluid IL-6 concentration.^{14–17}

Many recent studies have demonstrated the efficacy of LIA, however, to our knowledge, no published study has demonstrated LIA impacts on length of stay and cost savings. This article discusses the rapid recovery following hip and knee arthroplasty using LIA and its impacts on length of stay, destination of discharge and potential cost savings.

Methods

Study design

Prospective study, one surgeon in one institution, of primary joint replacements including 200 knees, and 165 hips over 2 years period from 1 July 2014 to 30 June 2016. Exclusion criteria included cases done for hip fractures, and unicompartmental knee replacements. Our data is compared with Surgical Variance Report 2017 conducted by the Royal Australasian College of Surgeons (RACS)/Medibank for the same period. In Australia, RACS and Medibank work together to publish updated reports to create opportunities to provide guidance on best practice. The report used in this study included de-identified Medibank claims data from the two financial years 2015 and 2016. The variables included in the comparison between the two groups were: age of patients, length of stay, percentage of patients transferred to rehabilitation, ICU or readmitted within 30 days, and average separation cost.

Injection technique

LIA technique has four core components as shown in Figures S1–S5; the preparation of drug cocktail, the injection technique, intra-articular epidural catheter placement, and the compression bandage application; used in TKA only, this helps not only reduce joint swelling, but also maintains the LIA mixture in the periarticular tissues.

Periarticular mixture

The mixture consists of ropivacaine 2.0 mg/mL in a 200 mL bag. Before mixing it with the drugs, typically 25 mL is removed, thus 350 mg of ropivacaine is mixed with 30 mg ketorolac, 4 mg dexamethasone and 0.5 mg adrenaline. Variations to the LIA were to reduce the ropivacaine to 150 mL in small patients with weight lower than 55 kg, increase the ropivacaine to 200 mL in patients over 100 kg, and to remove the ketorolac in patients known to have anaphylaxis to NSAIDs. Before wound closure, a catheter is inserted into the joint for the mixture injection on the morning of the first post-operative day. The catheter used is 16-gauge Tuohy

needle, 18-gauge epidural catheter, and a 0.22- μ high-performance antibacterial flat epidural filter which prevents bacterial passage to the joint.¹³

THR injection technique

At the time of this study our default approach was mini-posterior approach. About 150–200 mL of the mixture is injected in four stages: the first injection (50 mL) is made into the subcutaneous tissue and proximal part of gluteus maximus muscle, the needle is put perpendicular to the skin edges and with a depth of 20–30 mm in a 'moving needle' technique. The second injection (75 mL) is applied after placement of the acetabular components; the injection is placed into the periarticular tissues superiorly, anteriorly, and inferiorly through the joint capsule. After reduction of the joint and closure of the posterior capsule; the injection includes the external rotators, quadratus femoris and the vastus lateralis muscle. The wound catheter is placed through the skin and deep fascia, into the joint between gluteus medius and the superior edge of the repaired piriformis tendon. A small volume is injected down the catheter to ensure it is patent before closing the bursa over the posterior Gluteus Medius. The final injection of the remaining mixture is injected into gluteus maximus muscle and its insertion onto the proximal fascia lata.

TKA injection technique

About 175 mL of drug mix is injected in four stages; the first injection (50 mL) is made by injecting laterally to medially across the thigh approximately 20 cm above the patella deep to the deep fascia as shown in Figure S1, then separately anteriorly to posteriorly, medial to the femur as shown in Figure S2. The second injection is made after the bone cuts, meniscectomy and clearing the posterior recesses. About 25 mL is injected through the posterior capsule near the femur in each of the medial and lateral compartments as shown in Figure S3. The third injection is made after insertion of the implant components while waiting for cement polymerization into the synovium and capsule, tissues deep to the medial collateral ligament insertion, and Gerde's tubercle anterolaterally. The final injection of 25 mL is via the wound catheter into the joint after wound closure as shown in Figure S4. The 18-gauge wound catheter is inserted through a 16-gauge Touhy needle antero-superiorly, whilst pulling the vastus medialis oblique laterally to ensure the catheter will not be incorporated into the capsular closure suture. The catheter is placed along the medial femoral condyle to allow the tip of the catheter to face the posterior capsule.

The compression bandage is applied from toes to high thigh in three different layers; one layer of soft padding, one layer of crepe bandage, and outer layer of elastic adhesive bandage as shown in Figure S5. The bandage was recommended by Kerr and Kohan in 2008, the inventor of the LIA.¹³ Another study confirmed the benefits of the compression bandage in TKA and demonstrated the improvement of LIA with compression bandage.¹⁸

Top-up at 16–24 hours

The mixture composed of ropivacaine 100 mg (10 mL 1%), dexamethasone 4 mg, ketorolac 30 mg, adrenaline 0.5 mg, and NaCl

0.9% 10 mL, combined in a 25 mL syringe. The mix is injected through the catheter on the morning of the first post-operative day. Adrenaline is not used for knees as leakage into the subcutaneous tissues may cause skin necrosis. After this injection, the wound catheter is removed. Patients with eGFR <30 mL/h do not receive the ketorolac at this stage.

Oral and topical medications

The patients were routinely prescribed paracetamol 1 g, Norspan 5 (buprenorphine 5µg/h), meloxicam 7.5 mg bd, Movicol i sachet bd, tramadol 50-100 mg four hourly prn. The meloxicam was reduced to daily in patients with an eGFR 30–55 mL/h, and not given if the eGFR was less than 30 mL/h.

Pre-operative discharge planning

The Risk Assessment and Prediction Tool (RAPT), developed by Oldmeadow at Alfred Hospital in Victoria in 2001, is utilized to predict the discharge destination after joint replacement surgery and helps align the expectations of patients after surgery. The accuracy of RAPT has been validated.^{19,20} Patients with scores below 6 usually require inpatient rehabilitation, while those who have RAPT score above 6 will usually be discharged directly home, and those with a RAPT score greater than 9 are most likely to go home on day 1 after surgery.

DVT prophylaxis

The default deep vein thrombosis (DVT) prophylaxis was aspirin (enteric coated form) 100 mg daily,²¹ compression stockings of 20–30 mmHg during daylight hours and early, frequent mobilization and avoidance of sitting. The essence of LIA is that it is highly efficient in acute post-operative pain management without adverse systemic effects, it allows early mobilization within hours post-operative. Stratification of the patients to receive potent anticoagulants are reserved for instances such as previous or family history of thromboembolism, hypercoagulability states, immobility prior to surgery, or if requiring powerful anticoagulants prior to surgery.²¹ Compression bandaging is applied for TKA for 48 h, and class 2 stockings providing 20–30 mmHg compression for all joint replacements were used.

Estimation of expenses

The patients included in our study were private patients, but the hospital expenses used in our study were extrapolated from the un-insured patients who have been done privately. Hospital expenses included theatre fee, implants, hospital bed days. Surgeon, assistant and anaesthetist were based on the Medibank Private rate for fair comparison. Out of pocket expenses were not included as the Medibank data could not accurately assess bills not sent to Medibank. Discharge medications were billed to both insured and un-insured patients. Rehabilitation expenses were estimated from RACS/Medibank report. The RACS/Medibank data refers to separation cost of patients including the total charges for the initial hospital stay; payments made by Medibank, Medicare and the patient.

They make comment about 'out of pocket expenses' but only those alerted to Medibank. The billing platforms used by different surgeons will not universally inform Medibank of surgeons for instance using the Australian Medical Association fee list, and we have removed this from the calculation.

Routine physician involvement is not part of our rapid recovery program. The patients generally have stable medical conditions or are not suitable for elective surgery. We have not allowed an expense in this category, nor do we know what proportion of the separation cost in the RACS/Medibank report is spent on this.

Cost of hip replacement

The Medibank report provided a \$11 015 average for rehabilitation per patient. Multiplying this by the incidence of rehabilitation (36%) gives \$3965.4, totalling the average total cost per hospital separation \$26 734. For our series, we assumed the typical cost to insurers was the same as for our un-insured patients paying out of pocket, theatre fees, bed fee and cost of prosthesis. We applied an implant fee of \$9756 as typically paid by our un-insured patients. The series did however include 10 hip resurfacings, and two cemented hip arthroplasties. Out of pocket expenses for surgical fees have been ignored to provide a fair comparison, and we used the same rehabilitation fee multiplied by our rehabilitation incidence of 7%, \$771, totalling \$17 813.

Cost of knee replacement

The average rehabilitation cost per patient is \$11 015 multiplied by the incidence of rehabilitation (43%) gives average rehabilitation cost per patient of \$4736, adding their initial hospitalization of \$22 769, thus totalling \$27 505. We applied an implant fee of \$8490 as paid by our un-insured patients. Out of pocket expenses for surgical fees have been ignored to provide a fair comparison, and we used the same rehabilitation fee multiplied by our rehabilitation incidence of 4.5%, \$495, totalling \$16 437.

Results

Total hip replacement

The median age of hip patient in our study is 69 years old (range 39 to 91 years) in line with the RACS/Medibank data, also with a mean of 69 years. The median number of nights that a patient stayed in hospital is two nights (average 2.02 nights). This is lower than the national data with a median number of nights was five nights. The percentage of patients that have been transferred to inpatient rehabilitation in our series is 7%, compared to 36% in RACS/Medibank national data. There were no patients transferred to ICU in our study compared to 4% of overall hospital separations among national data. In our study, the number of readmissions was six patients (3.90%) distributed among these complications; nausea, gastritis, greater trochanter fractures, and one deep infection seeded from poor dentition. The RACS/Medibank data demonstrates 6% readmissions (for all causes) to a hospital within 30 days. The saving in our system is \$8921 or 36%. Table S1 compares our data with the national data.

Total knee arthroplasty

Our sample median age is 69 years old (range 49 to 92 years). This is identical to the RACS/Medibank report's median patient age. The median number of nights in our data is one night, average 1.73 nights, whereas the median number of nights in the report data was five nights. The percentage of patients transferred to inpatient rehabilitation in our data was only 4.5%, lower than the RACS/Medibank's data; the percentage is 43%. Patients were transferred to ICU is 0.5% in our study compared to patients were transferred to ICU is 3% of overall hospital separations. In our study, the incidence of readmissions was 6% distributed among these complications; DVT/PE, haemorrhage/hematoma, stiffness, GIT bleeding, and social-related readmission. RACS/Medibank data indicates 7% of patients were readmitted (for all causes) to a hospital within 30 days. The saving in our system is \$11 068 or 40%. Table S2 compares our data with the national data.

Discussion

Cost of orthopaedic interventions is currently significantly spent on hospital stay and rehabilitation expenses. The length of stay is dramatically affected by patient mindset and the application of rapid recovery principles. Direct post-operative pain drives the patient to stay longer in the hospitals and struggles with physiotherapy instructions. Being comfortable in the two days following surgery gives the patient the confidence to mobilize and recover faster, it also allows psychological support from pain phobia after surgery.

To surgeons and anaesthetists new to LIA, side effects of ropivacaine is a major fear, but Kerr and Kohan in their series of 3000 patients utilizing LIA, had no incidences of major toxicity. They still had a low incidence of nausea, vomiting, and postural hypotension while trying to walk the patient 3 h post-operatively,¹³ however, hypotension seems more idiosyncratic rather than predictable. The adrenaline and compression bandage not only prolong the action of the drug mix, but also delay its washout from the injected tissues,¹⁸ and minimizes the systemic blood absorption. This has been shown on serial blood levels to be well away from neurotoxic levels, and an order of magnitude away from cardiotoxic doses.¹³

The incidence of patient's needs for inpatient rehabilitation may increase due to their fear of pain and inability to mobilize without pain. Utilization of inpatient rehabilitation after lower limb joint replacements are variable among countries; high uptake in USA and Switzerland versus low uptake in Canada and UK.^{22,23} The incidence of inpatient rehabilitation in Australia is high by international standards. In a subset of our series 23 patients with a RAPT score of less than 7, 48% (11 patients) went to rehabilitation. Thus, we do not use the RAPT score as a rule, just a guideline. Of 342 patients with a RAPT score of greater than 6, only nine went to rehabilitation (2.6%). These variations from Oldmeadows predictor seem to occur as a result of patient's psychological condition- in particular anxiety and depression delay discharge and increase the likelihood of rehabilitation. Conversely, some patients are keen to be discharged directly home with low-level support of friends and family. A randomized controlled trial from Australia in 2017 demonstrated that patients with home program are not disadvantaged

compared to those who are transferred to inpatient rehabilitation.²⁴ Another Canadian randomized controlled trial stated that there was no difference between patients who have received inpatient rehabilitation versus those who have received home rehabilitation in terms of pain, patient satisfaction and functional outcomes. The study concluded that home-based rehabilitation program is a cost-effective protocol after knee or hip replacement.²⁵ Furthermore, one study shows cost-effectiveness is decreased if the patient is transferred to an inpatient rehabilitation after TKA.²⁶

Monetary savings associated with fast track TKA or THR with LIA technique come from the short length of stay and avoidance of inpatient rehabilitation as shown above from the cost estimation. Savings of more than \$11 million per 1000 total knee replacements, and savings of more than \$9 million per 1000 THRs are possible. However, typical contracts between hospitals and private health insurance funds discourage early discharge, using a 'low outlier' payment for short stay patients. This belies the intensive nature of the hospital stay; indeed, most of the costs are loaded up into the first 24 hours. In Australia acute home nursing is a rarity but were on call nursing staff available to visit patients at home, many patients could be undertaken as day surgery. The current system is punitive, with some insurers refusing to pay for readmission of patients, even though the insurers are the main financial beneficiaries of the short length of stay.

The limitations of our study are that we do not have actual hospital billing data for the patients charged to the insurers. The figures we used extrapolating our private un-insured patients will be overstated relative to contracts of the insurers, thus the variation in expense is expected to be greater than we have stated. Secondly, the surgeries were performed by a single surgeon in a single institution. Conversely, we used a broad pool of anaesthetists, who have accepted substantial standardization of anaesthetic approach. Independence of the anaesthetists has been maintained, but narcotics and inhalational anaesthetic agents have been minimized, and where spinal anaesthetic has been preferred, intrathecal opioids either avoided or kept to a minimal level. A further limitation is that some cases in the RACS/Medibank data will have also had LIA, but perhaps the hospital environment they worked in did not pursue LIA and rapid recovery protocols to the same degree, or an early discharge was not incentivized for the treating practitioners and hospitals. This paper reviews our practice from 2014–2016 and does not reflect further progress with respect to post-operative postural hypotension, reduction in our use of buprenorphine and anterior surgical approach for hip replacement surgery.

Conclusion

The readiness for patient discharge is determined by patient expectations, comfort and ability to mobilize safely. LIA is a useful method enabling patients to have shorter hospitalization, lower rehabilitation incidence, and a resultant reduction in health expenditure, without increasing the risk of adverse outcomes.

Conflicts of interest

None declared.

References

- Bourne RB, Chesworth BM, Davis AM, Mahomed NN, Charron KD. Patient satisfaction after total knee arthroplasty: who is satisfied and who is not? *Clin. Orthop. Relat. Res.* 2010; **468**: 57–63.
- Beswick AD, Wylde V, Gooberman-Hill R, Blom A, Dieppe P. What proportion of patients report long-term pain after total hip or knee replacement for osteoarthritis? A systematic review of prospective studies in unselected patients. *BMJ Open* 2012; **2**: e000435.
- Wylde V, Gooberman-Hill R, Horwood J *et al.* The effect of local anaesthetic wound infiltration on chronic pain after lower limb joint replacement: a protocol for a double-blind randomised controlled trial. *BMC Musculoskelet. Disord.* 2011; **12**: 53.
- Sinatra RS, Torres J, Bustos AM. Pain management after major orthopaedic surgery: current strategies and new concepts. *J. Am. Acad. Orthop. Surg.* 2002; **10**: 117–29.
- DeWeese FT, Akbari Z, Carline E. Pain control after knee arthroplasty: intraarticular versus epidural anesthesia. *Clin. Orthop. Relat. Res.* 2001; **392**: 226–31.
- Horlocker TT, Cabanela ME, Wedel DJ. Does postoperative epidural analgesia increase the risk of peroneal nerve palsy after total knee arthroplasty? *Anesth. Analg.* 1994; **79**: 495–500.
- Horlocker TT, Hebl JR, Kinney MA, Cabanela ME. Opioid-free analgesia following total knee arthroplasty—a multimodal approach using continuous lumbar plexus (psoas compartment) block, acetaminophen, and ketorolac. *Reg. Anesth. Pain Med.* 2002; **27**: 105–8.
- Hebl JR, Horlocker TT, Schroeder DR. Neuraxial anesthesia and analgesia in patients with preexisting central nervous system disorders. *Anesth. Analg.* 2006; **103**: 223–8.
- Busch CA, Shore BJ, Bhandari R *et al.* Efficacy of periarticular multimodal drug injection in total knee arthroplasty. A randomized trial. *J. Bone Joint Surg. Am.* 2006; **88**: 959–63.
- Fischer HB, Simanski CJ, Sharp C *et al.* A procedure-specific systematic review and consensus recommendations for postoperative analgesia following total knee arthroplasty. *Anaesthesia* 2008; **63**: 1105–23.
- Naylor J, Harmer A, Fransen M, Crosbie J, Innes L. Status of physiotherapy rehabilitation after total knee replacement in Australia. *Physiother. Res. Int.* 2006; **11**: 35–47.
- Christelis N, Wallace S, Sage CE *et al.* An enhanced recovery after surgery program for hip and knee arthroplasty. *Med. J. Aust.* 2015; **202**: 363–8.
- Kerr DR. *Local Infiltration Analgesia: A Technique to Improve Outcomes after Hip, Knee or Lumbar Spine Surgery*, 1st edn. London: CRS Press, 2012.
- Christensen CP, Jacobs CA, Jennings HR. Effect of periarticular corticosteroid injections during total knee arthroplasty. A double-blind randomized trial. *J. Bone Joint Surg. Am.* 2009; **91**: 2550–5.
- Ikeuchi M, Kamimoto Y, Izumi M *et al.* Effects of dexamethasone on local infiltration analgesia in total knee arthroplasty: a randomized controlled trial. *Knee Surg. Sports Traumatol. Arthrosc.* 2014; **22**: 1638–43.
- Busch CA, Whitehouse MR, Shore BJ, MacDonald SJ, McCalden RW, Bourne RB. The efficacy of periarticular multimodal drug infiltration in total hip arthroplasty. *Clin. Orthop. Relat. Res.* 2010; **468**: 2152–9.
- Chia SK, Wernecke GC, Harris IA, Bohm MT, Chen DB, Macdessi SJ. Peri-articular steroid injection in total knee arthroplasty: a prospective, double blinded, randomized controlled trial. *J. Arthroplast.* 2013; **28**: 620–3.
- Andersen LO, Husted H, Otte KS, Kristensen BB, Kehlet H. A compression bandage improves local infiltration analgesia in total knee arthroplasty. *Acta Orthop.* 2008; **79**: 806–11.
- Hansen VJ, Gromov K, Lebrun LM, Rubash HE, Malchau H, Freiberg AA. Does the risk assessment and prediction tool predict discharge disposition after joint replacement? *Clin. Orthop. Relat. Res.* 2015; **473**: 597–601.
- Dauty M, Schmitt X, Menu P, Rousseau B, Dubois C. Using the risk assessment and predictor tool (RAPT) for patients after total knee replacement surgery. *Ann. Phys. Rehabil. Med.* 2012; **55**: 4–15.
- Haykal T, Kheiri B, Zayed Y *et al.* Aspirin for venous thromboembolism prophylaxis after hip or knee arthroplasty: an updated meta-analysis of randomized controlled trials. *J. Orthop.* 2019; **16**: 312–9.
- Benz T, Angst F, Oesch P *et al.* Comparison of patients in three different rehabilitation settings after knee or hip arthroplasty: a natural observational, prospective study. *BMC Musculoskelet. Disord.* 2015; **16**: 317.
- Hart A, Bergeron SG, Epure L, Huk O, Zukor D, Antoniou J. Comparison of US and Canadian perioperative outcomes and hospital efficiency after Total hip and knee Arthroplasty. *JAMA Surg.* 2015; **150**: 990–8.
- Naylor JM, Hart A, Mittal R, Harris I, Xuan W. The value of inpatient rehabilitation after uncomplicated knee arthroplasty: a propensity score analysis. *Med. J. Aust.* 2017; **207**: 250–5.
- Mahomed NN, Davis AM, Hawker G *et al.* Inpatient compared with home-based rehabilitation following primary unilateral total hip or knee replacement: a randomized controlled trial. *J. Bone Joint Surg. Am.* 2008; **90**: 1673–80.
- Losina E, Walensky RP, Kessler CL *et al.* Cost-effectiveness of total knee arthroplasty in the United States: patient risk and hospital volume. *Arch. Intern. Med.* 2009; **169**: 1113–21.

Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1. THR data summary.

Table S2. TKA data summary.

Figure S1. First injection is applied from laterally to medially across the thigh approximately 20 cm above the patella deep to the deep fascia as shown in Figure 1.

Figure S2. The injection from anteriorly to posteriorly, medial to the femur.

Figure S3. 25 mL is injected through the posterior capsule near the femur in each the medial and lateral compartments.

Figure S4. The final injection of 25 mL is via the wound catheter into the joint after wound closure.

Figure S5. The compression bandage is applied from toes to high thigh in three different layers; the outer layer of elastic adhesive bandage.