■ KNEE ARTHROPLASTY: MANAGEMENT FACTORIALS

Cost-effective peri-operative pain management

ASSURING A HAPPY PATIENT AFTER TOTAL KNEE ARTHROPLASTY

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Aims

The aim of this study was to determine the optimal regimen for the management of pain following total knee arthroplasty (TKA) by comparing the outcomes and cost-effectiveness of different protocols implemented at a large, urban, academic medical centre.

Patients and Methods

Between September 2013 and September 2015, we used a series of modifications to our standard regimen for the management of pain after TKA. In May 2014, there was a department-wide transition from protocols focused on femoral nerve blocks (FNB) to periarticular injections of liposomal bupivacaine. In February 2015, patient-controlled analgesia (PCA) was removed from the protocol while continuing liposomal bupivacaine injections. Quality measures and hospital costs were compared between the three protocols.

Results

The cohort being treated with PCA-less liposomal bupivacaine injections had a significantly higher percentage of patients who were discharged to their home ($p = 0.010$) and a significantly shorter length of stay ($p < 0.001$). Patient-reported Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) scores relating to pain being "well-controlled" and "overall pain management" also favoured this cohort ($p = 0.214$ and $p = 0.463$, respectively), in which cost was significantly lower compared with the other two cohorts ($p = 0.005$).

Conclusion

The replacement of FNBs injections and the removal of PCAs, both of which are known to be associated with high rates of adverse outcomes, and the addition of liposomal bupivacaine periarticular injections to a multimodal pain regimen, led to improvements in many quality measures, HCAHPS pain scores, and cost-effectiveness.

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In the current healthcare environment of bundled models of payment, substantial efforts are being made to maximise the value of the care that is delivered. Among the many value-based initiatives that hospitals have explored, the use of standardised, evidence-based protocols and clinical care pathways have been shown to improve efficiency and minimise the use of resources.[1-6] In striving to increase value, emphasis has recently been placed on peri-operative pain management protocols for patients who undergo total joint arthroplasty. Given the wide variation in pain management strategies between institutions, refining existing protocols not only provides opportunities for improvements in quality and satisfaction, but further optimises cost-effectiveness and value-based care.

Despite advancements in the peri-operative treatment of patients undergoing arthroplasty, the management of pain remains a challenge. Approximately 20% of patients are not satisfied with the outcome of their total knee arthroplasty (TKA),[7] which has been partially attributed to lack of adequate control of pain following these procedures.[8] Currently, there are no well-defined guidelines for the optimal pain management protocol in patients undergoing TKA. Traditional methods of management include the use of opioids, patient-controlled analgesia (PCA) and peripheral nerve blocks.[9] Although effective in reducing pain,[10] there is increasing evidence of adverse events with these techniques. Peripheral nerve blocks have been associated with an increased

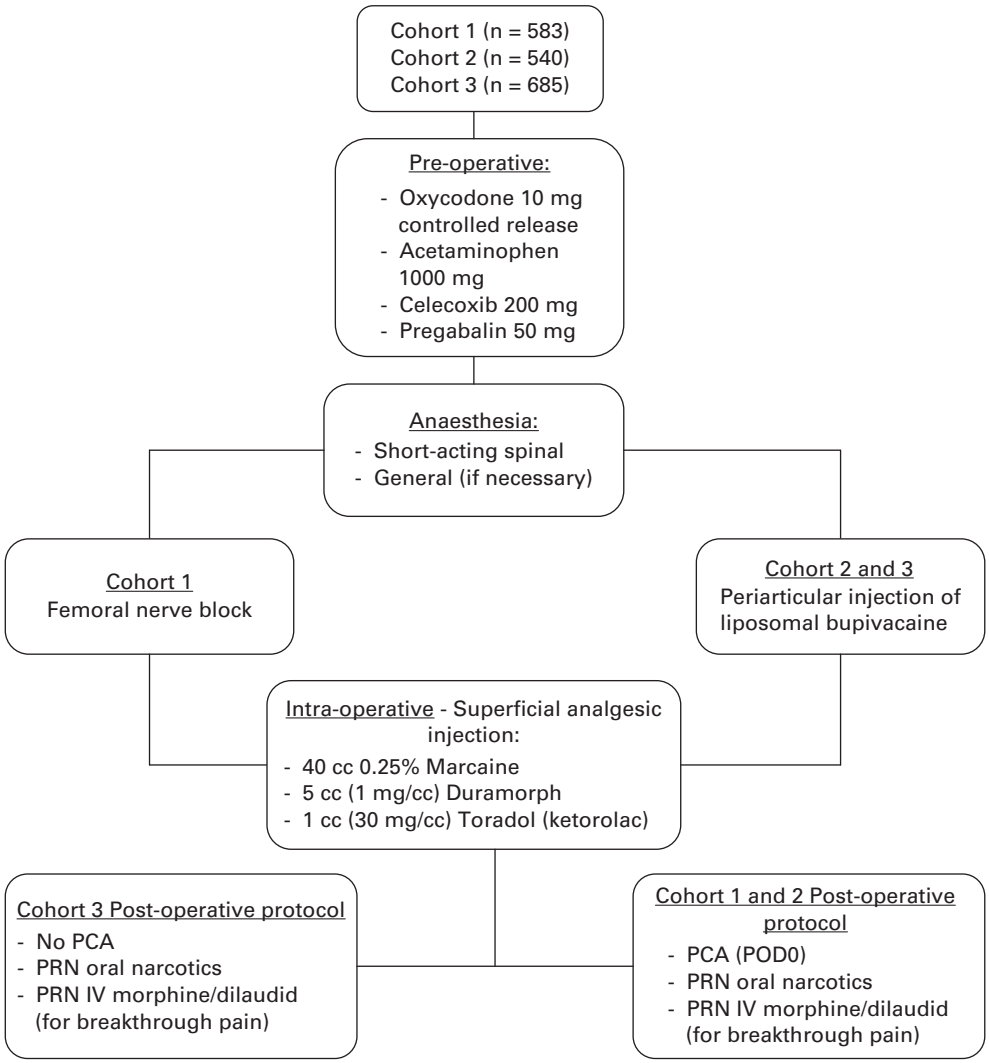

Fig. 1

Protocol for the management of peri-operative pain in total knee arthroplasty in the three cohorts (PCA, patient-controlled analgesia; IV, intravenous; POD0, Post-operative Day 0).

risk of falls, nerve injury and temporary loss of motor function, thereby delaying rehabilitation.[11-13] The side effects of opioids include respiratory, haemodynamic, urinary, and gastrointestinal disturbances.[14-18] As a result, there has been a shift towards reducing opioid consumption, using a multimodal analgesic approach including long-acting agents such as periarticular injections of liposomal bupivacaine.[19] The American Society of Anesthesiologists (ASA) has supported this movement and recommends a combination of pain-managing strategies in order to reduce opioid consumption.[15,20] Early studies have shown shorter lengths of stay, improved control of pain and increased satisfaction with the use of these measures.[1,16-24]

To develop an optimal pain management protocol, we undertook a series of modifications to the standard regimen in TKA. The use of liposomal bupivacaine is controversial and expensive when pharmacy costs alone are considered. Decisions about cost-effectiveness in the new value-based era need to be based on the entire cost of an episode, rather than an examination of isolated costs previously reported.[1-6] This study highlights our experiences with the implementation of these protocols. By using optimised protocols for the management of pain and minimising the use of opioids, we hypothesised that a decrease in complications with at least equivalent control of pain would lead to improved cost-effectiveness.

Patients and Methods

Between September 2013 and September 2015, all patients undergoing primary unilateral TKA by 24 surgeons at NYU Langone Medical Center were identified. During this period, three different protocols for the management of pain were used, their differences focusing on whether a femoral nerve block (FNB) or liposomal bupivacaine periarticular injections were used intra-operatively and whether PCA was used post-operatively. Patients were excluded from the study if their pain management regimens

did not strictly adhere to the protocol provided at the time of their surgery. Three cohorts were included in the study (Fig. 1). Cohort 1 consisted of patients who received FNB intra-operatively and PCA for the first 24 hours post-operatively. Cohort 2 included all patients who received liposomal bupivacaine injections instead of FNB following a department-wide transition in May 2014. Cohort 3 consisted of all patients who underwent TKA after February 2015, when PCA was removed from the protocol while continuing liposomal bupivacaine injections.

The protocol for the management of pre-operative pain for each period of time was identical and consisted of one administration of oral analgesics (10 mg oxycodone, 200 mg celecoxib, 1000 mg acetaminophen, 50 mg of pregabalin). Within the operating room, a short-acting anaesthetic was administered using either 3 ml 3% chloroprocaine or 3 ml 0.5% ropivacaine. Under the rare circumstances that a spinal anaesthetic was contraindicated, general anaesthesia was used with intravenous midazolam, fentanyl and propofol for the maintenance of anaesthesia throughout the procedure.

A tourniquet was used and all patients received a periarticular injection (40 cc 0.25% Marcaine (Hospira, Lake Forest, Illinois), 5 cc 5 mg Duramorph (West-Ward, Eatontown, New Jersey) and 1 cc 30 mg Toradol (Regency, Shirley, New York)). In cohort 1, an ultrasound-guided injection of 20 ml of 0.25% bupivacaine was administered. A liposomal bupivacaine periarticular injection (Exparel; Pacira Pharmaceuticals, Parsippany, New Jersey) used in cohorts 2 and 3 consisting of 20 cc of liposomal bupivacaine (13 mg/cc) in 40 cc to 100 cc 0.9% normal saline and was dispersed equally throughout the posterior capsule and the overlying periosteum and soft tissue.

All patients underwent the same standardised post-operative clinical pathway and rehabilitation. For the control of pain, they were offered oral oxycodone 5 mg or 10 mg or morphine or hydromorphone 0.2 mg to 0.5 mg prn intravenously for breakthrough pain. In cohorts 1 and 2, receiving PCA, either morphine, hydromorphone, or fentanyl was administered for the first 24 hours post-operatively. Physiotherapy began within the first post-operative day and patients were encouraged to mobilise as tolerated. The decision to discharge the patients to their home or to a rehabilitation facility was made by the surgeon and social support team based on the patient's ability to complete milestones, including walking 100 feet and climbing stairs, as well as individual social factors such as the availability of home support and transportation.

The baseline demographics of the patients including age, gender, body mass index (BMI), and ASA grade[25] were collected using our electronic medical record system. Our payment data-reporting system was used to obtain the total hospital bill, including the amount that the hospital paid for the entire episode of care. Costs were then calculated for the entire length of stay and reported as relative percentages between the cohorts. The total morphine milligram-equivalent (MME) doses of narcotics consumed during four post-operative days were recorded and the pain scores, which were based on an 11-point visual analogue numeric pain rating scale (0 to 10, best to worst) collected at regular two hour to eight hour intervals by the nursing staff.[26] Progress with physiotherapy was recorded based on the patient's ability to climb stairs and walk more than 100 feet on each post-operative day.

Finally, we recorded the length of stay, whether the patients went home or to a rehabilitation centre at discharge, the 30-day re-admission rates and the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) scores from our Centre for Quality and Patient Safety database. HCAHPS surveys are disseminated to patients recently discharged from an acute care hospital for a medical or surgical admission. The survey includes ten measures related to their perspectives of care. Each domain contains between one and three questions and is rated on a scale from one to four (one to ten for overall rating of hospital) with four or ten being the most satisfactory. The most affirmative answer for each measure is referred to as "top-box", which is then used to calculate a composite score for the hospital. We focused on two domains in this study that were directly relevant to our patient population; pain management and overall rating of the hospital.

Pain management was assessed by the questions:

- during this hospital stay, how often was your pain well controlled?;

- during this hospital stay, how often did the hospital staff do everything they could to help you with your pain?

Overall rating of the hospital was assessed by the question:

- using any number from 0 (worst) to 10 (best), what number would you use to rate this hospital during your stay?

Statistical analysis. Baseline and demographic characteristics were summarised by standard descriptive summaries using means and standard deviations for continuous variables such as age and BMI and percentages for categorical variables such as gender and ASA grades. All data was managed using Excel software (Microsoft Corporation, Redmond, Washington). Analysis of variance tests were used to compare continuous variables while a chi-squared analysis was performed to compare categorical variables. A p-value of < 0.05 determined statistical significance. All analyses were done using SPSS Statistics software (SPSS Inc., Chicago, Illinois).

Results

Of the 1808 patients included in the study, 583 were in cohort 1527 in cohort 2 and 698 in cohort 3. The mean age in the three cohorts was similar (64.9 years to 65.8 years; $p = 0.86$) as well as the distribution of ASA grades. There was a significantly higher proportion of women in cohort 3 ($p = 0.04$) and a significantly lower BMI in cohort 2 ($p = 0.05$). The demographic variables in the three cohorts are shown in Table I.

Table I. Comparison of the demographics of the patients

	Cohort 1 (+ Femoral nerve block, no liposomal bupivacaine, + patient-controlled analgesia) (n = 583)	Cohort 2 (no femoral nerve block, + liposomal bupivacaine, + patient-controlled analgesia) (n = 540)	Cohort 3 (no femoral nerve block, + liposomal bupivacine, no patient-controlled analgesia) (n = 685)	p-value
Mean age (SD)	65.8 (9.9)	64.9 (10.5)	65.3 (10.0)	0.861
Female gender, n (%)	384 (*65.9*)	361 (*66.9*)	498 (*72.7*)	0.037
Mean BMI, kg/m^2 (SD)	32.1 (7.1)	31.7 (7.1)	32.5 (6.7)	0.047
ASA, n (%)				0.192
1	13 (*2.3*)	13 (*2.4*)	8 (*1.2*)	
2	406 (*69.6*)	370 (*68.6*)	433 (*63.3*)	
3	163 (*28.0*)	154 (28.6)	236 (*34.4*)	
4	12 (*2.0*)	2 (*0.4*)	6 (*0.9*)	
Interquartile range (25th to 75th percentiles)	2 to 3	2 to 3	2 to 3	

ASA, American Society of Anesthesiologists; BMI, Body mass index

Table II. Comparison of quality metrics

Quality metrics	Cohort 1 (+ Femoral nerve block, no liposomal bupivacaine, + patient-controlled analgesia) (n = 583)	Cohort 2 (no femoral nerve block, + liposomal bupivacaine, + patient-controlled analgesia) (n = 540)	Cohort 3 (no femoral nerve block, + liposomal bupivacine, no patient-controlled analgesia) (n = 685)	p-value
Discharged home, n (%)	421 (*72.2*)	420 (*77.8*)	572 (*83.5*)	0.010
30-day re-admissions, n (%)	15 (*2.6*)	5 (*1.0*)	15 (*2.2*)	0.083
LOS, days	3.2	3.1	2.7	< 0.001
HCAHPS – Pain management – "Always", n (%)	448 (*76.9*)	416 (*77.0*)	540 (*78.9*)	0.463
HCAHPS – Pain control – "Always", n (%)	400 (*68.7*)	376 (*69.6*)	504 (*73.6*)	0.214
HCAHPS - Global rating scale – Highest rating, n (%)	441 (*75.7*)	441 (*81.7*)	527 (*76.9*)	0.093
Cost, %	Ref. value	*+2.2*	*-2.6*	0.005

ASA, American Society of Anesthesiologists grade; HCAHPS, Hospital Consumer Assessment of Healthcare Providers and Systems; LOS length of stay

Pain scores, narcotic consumption, and progression with physiotherapy. There was no clinical difference in pain scores at any time after the first eight hours post-operatively in all groups. There were significantly higher pain scores in cohort 3 within eight hours immediately following surgery (1.2, cohort 1; 1.0, cohort 2; 4.0, cohort 3; $p < 0.001$) presumably due to the absence of PCA. It is not clear if this difference was clinically meaningful as visual analogue scale (VAS) pain scores of < 4 are not considered significant and are not treated at our institution as significant pain. The use of narcotics during the whole post-operative period was lowest in cohort 3 (66 MME, cohort 3; 82 MME, cohort 2; 96 MME, cohort 1; $p < 0.001$). There was a significantly higher prevalence of achieving physiotherapy milestones of both stair-climbing and walking for 100 feet in cohort 3 on the first post-operative day (47% (322/685), cohort 3; 30% (162/540), cohort 2; 16% (93/583), cohort 1; $p < 0.001$), while eventual achievement was similar in cohorts 2 and 3 during the whole post-operative period (93% (502/540), cohort 2; 90% (617/685), cohort 3, $p < 0.001$).

Quality metrics. A significantly higher percentage (83.5%; 572/685) of patients in cohort 3 were discharged to their home (72.2% (421/583) *versus* 77.8% (420/540) *versus* 83.5% (572/685); $p = 0.01$) rather than to a rehabilitation facility. The 30-day all-cause rate of re-admission was not statistically significantly different between the cohorts ($p = 0.08$). The mean length of stay was significantly shorter in cohort 3 (2.7 days) compared with the other two cohorts (3.2 *versus* 3.1 *versus* 2.7, $p < 0.001$). The HCAHPS top-box scores relating to pain being "well-controlled" and "overall pain management" favoured cohort 3, although it did not reach statistical significance ($p = 0.21$ and $p = 0.46$ respectively). The global rating (nine to ten "highest rating") between the cohorts were: 75.7% (441/583), cohort 1; 81.7% (441/540), cohort 2; 76.9% (527/685),

cohort 3; p = 0.09. The cost was significantly lower in cohort 3 compared with the other two and there was a mean saving of 2.63% for the hospitalisation compared with cohort 1 and 4.81% compared with cohort 2 (Table II). These metrics were improved or stable while decreasing opioid use, improving rates of achieving physiotherapy milestones and decreasing cost compared with cohort 1.

Discussion

As payment paradigms for TKA continue to shift towards performance-based models, the tolerance for inefficiencies and sub-optimal care will continue to be narrow. Thus, hospitals are being pressed to refine their practices to meet these heightened expectations. One such aspect that has been scrutinised and serves as an ongoing challenge among all surgical procedures is the peri-operative management of pain. In response to concerns about adverse events with a peripheral nerve block and the use of opioids, alternative protocols have been investigated. Long-acting liposomal bupivacaine has gained popularity as a periarticular injection given its potential to provide extended lengths of pain relief.[2] This is made possible by its lipid-based multivesicular makeup, allowing for release into the surrounding tissues for up to 72 hours post-operatively.[3] Despite these favourable mechanisms, inconsistent reports of improved control of pain have been reported in the literature when liposomal bupivacaine injections were compared with traditional injections and FNBs in TKA.[4-6] The benefits of a liposomal bupivacaine injection are dependent upon the technique by which it is administered and its consistent dispersion throughout the soft tissues is required for its optimal effect.

Although adequate control of pain is a major contributor to the outcome of TKA, improving it compared with existing forms of management may not be the primary goal of modern protocols of pain management. The control of pain is only one component of overall management and various regimens must be weighed against their individual side-effect profile and functional outcomes to determine their clinical benefit and cost-effectiveness during the entire episode of care. We found that modifying two aspects of our institution's protocol for the management of pain, the elimination of FNBs and the removal of PCAs, which are both known to be associated with high rates of adverse outcomes, led to improvements in many quality measures coincident with the addition of liposomal bupivacaine injections. Reduced length of stay, more patients being discharged to their own home, reduced 30-day re-admission rates and significantly reduced hospital costs were achieved while maintaining equivalent pain scores and increasing patient satisfaction.

Post-operative pain and delays in improvement in motor function are well-known causes of an increased length of stay following TKA.[22,27] Given that pain scores were equivalent among all cohorts, and that improvements in motor function in cohort 3 were achieved at a quicker and higher rate than with a FNB, we were able to identify that improved motor function and thus quicker achievement of physiotherapy milestones, may be the cause of the reduced length of stay that was seen in cohort 3. We also found a decreased consumption of narcotics post-operatively in cohort 3. The use of opioids is associated with other common causes of a prolonged length of stay including nausea, cognitive impairment, urinary retention and cardiorespiratory depression.[14,28-30] Although the exact reasons for a prolonged length of stay were not documented for the purposes of this study, this may be a topic for future investigation.

An increasingly emphasised component of value-based care initiatives is the improvement of patient satisfaction. The HCAHPS survey was specifically created to provide a method of measuring and comparing data on patient satisfaction among hospitals. The use of these surveys is multidimensional. It provides patients with the opportunity to express their satisfaction with the quality of care, while the public reporting of this data allows future patients to choose higher performing hospitals. Additionally, this data helps providers and payers monitor and improve the quality of care.[31] This study shows that our institution has been able to improve HCAHPS pain and global rating scores and significantly improve other quality metrics, which are less attributable to pain relief.

The initial response to these findings may be to attribute the higher HCAHPS scores to better pain scores in the cohort without PCA. However, there is evidence of a complex association between the control of pain and satisfaction, such as HCAHPS and pain severity scores, in which the intensity of pain is not a reliable predictor or indicator of a patient's satisfaction with their overall management.[32]

Previous studies have also shown the efficacy of liposomal bupivacaine injections in managing pain and improving quality after TKA. Kirkness et al[33] compared liposomal bupivacaine injections with a FNB using conventional bupivacaine and showed significantly shorter mean length of stay (3.1 days *versus* 3.6 days, p < 0.03) and a 5% reduction in hospital costs per patient (p = 0.033). Cien et al[34] reported a 7% reduction in mean hospital costs (p < 0.001), and a lower post-operative consumption of opioids with a significantly shorter length of stay in the liposomal bupivacaine injection group compared with FNB. Broome and Burnikel[35] found that, based on the costs, the requirement for ultrasound-guided placement, and the labour of additional treatment associated with femoral nerve catheters costs hospitals up to an additional $600 per patient.

There are several limitations to this study. First, it is retrospective. Secondly, it is likely that a learning curve for the administration of the liposomal bupivacaine injections could affect the results. Although each surgeon had the same training for administering the injections, there may have been an impact of different levels of experience with periarticular injections between the surgeons. The administration of liposomal bupivacaine has been shown to be

highly technique-dependent given that the diffusion potential is less than for other cocktails of analgesics which include bupivacaine.[36] Similarly, there may have been an institutional learning curve associated with the transition between the different protocols for the management of pain. Financial data reported by our medical centre can only be presented as a relative percentage and not in absolute values. This limits the study from offering a more robust financial analysis of the course of treatment associated with each analgesic that was studied. The cost of care can also vary significantly between countries. Although the data about costs which we present are applicable to the United States, it may not be possible to extrapolate these cost-savings to other countries, however, measurements of quality should be relevant to any location. Finally, there are many factors in a retrospective cohort study that can affect length of stay and the destination of the patients at discharge. Although the intervals of time between the cohorts are small, aspects of management and the demographics of patients presenting for TKA can change quite quickly, affecting the assessment of quality.

A recent shift from peripheral nerve blocks to periarticular injections and an emphasis on reducing the consumption of opioids has shown an increase in cost-effectiveness during an episode of care which includes a TKA and more favourable clinical outcomes and patient satisfaction. In the current study, the adoption of a multimodal protocol for the management of pain involving liposomal bupivacaine periarticular injections in conjunction with a PCA-less approach has proved to improve the value of care delivered at our institution significantly as measured by HCAHPS, outcome, quality, and financial metrics.

Take home message:

- An iterative approach to multimodal pain management after TKA can improve patient satisfaction.

- Cost-effectiveness evaluation needs to be applied over an entire episode of care to be meaningful.

- Functional milestones achievement and opioid minimisation can be improved with appropriate multimodal pain management after TKA.

Supplementary material

Tables showing the current pain management protocol for total joint arthroplasty at NYU Langone Medical Centre and illustration of the iterative approach to achieve these protocols are available alongside the online version of this article at www.bjj.boneandjoint.org.uk

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References

1. **Yu S, Szulc A, Walton S, Bosco J, Iorio R.** Pain control and functional milestones in total knee arthroplasty: liposomal dupivacaine versus femoral nerve block. *Clin Orthop Relat Res* 2017;475:110–117.
2. **Lonner J.** Role of liposomal bupivacaine in pain management after total joint arthroplasty. *J Surg Orthop Adv* 2014;23:37–41.
3. **Bramlett K, Onel E, Viscusi ER, Jones K.** A randomized, double-blind, dose-ranging study comparing wound infiltration of DepoFoam bupivacaine, an extended-release liposomal bupivacaine, to bupivacaine HCl for postsurgical analgesia in total knee arthroplasty. *Knee* 2012;19:530–536.
4. **Surdam JW, Licini DJ, Baynes NT, Arce BR.** The use of exparel (liposomal bupivacaine) to manage postoperative pain in unilateral total knee arthroplasty patients. *J Arthroplasty* 2015;30:325–329.
5. **Collis PN, Hunter AM, Vaughn MDD, et al.** Periarticular injection after total knee arthroplasty using liposomal bupivacaine vs a modified ranawat suspension: A prospective, tandomized study. *J Arthroplasty* 2016;31:633–636.
6. **Kuang M- J, Du Y, Ma J- X, et al.** The efficacy of liposomal bupivacaine using periarticular injection in total knee arthroplasty: A systematic review and meta-analysis. *J Arthroplasty* 2017;32:1395–1402.
7. **Schulze A, Scharf HP.** Satisfaction after total knee arthroplasty. Comparison of 1990-1999 with 2000-2012. *Orthopade* 2013;42:858–865.
8. **Dunbar MJ, Richardson G, Robertsson O.** I can't get no satisfaction after my total knee replacement: rhymes and reasons. *Bone Joint J* 2013;95-B(Suppl):148–152.
9. **Horlocker TT, Kopp SL, Pagnano MW, Hebl JR.** Analgesia for total hip and knee arthroplasty: a multimodal pathway featuring peripheral nerve block. *J Am Acad Orthop Surg* 2006;14:126–135.
10. **Parvizi J, Miller AG, Gandhi K.** Multimodal pain management after total joint arthroplasty. *J Bone Joint Surg [Am]* 2011;93-A:1075–1084.
11. **Joshi G, Gandhi K, Shah N, Gadsden J, Corman SL.** Peripheral nerve blocks in the management of postoperative pain: challenges and opportunities. *J Clin Anesth* 2016;35:524–529.
12. **Feibel RJ, Dervin GF, Kim PR, Beaulé PE.** Major complications associated with femoral nerve catheters for knee arthroplasty: a word of caution. *J Arthroplasty* 2009;24(Suppl):132–137.
13. **Sharma S, Iorio R, Specht LM, Davies-Lepie S, Healy WL.** Complications of femoral nerve block for total knee arthroplasty. *Clin Orthop Relat Res* 2010;468:135–140.
14. **Wheeler M, Oderda GM, Ashburn MA, Lipman AG.** Adverse events associated with postoperative opioid analgesia: a systematic review. *J Pain* 2002;3:159–180.
15. **American Society of Anesthesiologists Task Force on Acute Pain Management.** Practice guidelines for acute pain management in the perioperative setting: an updated report by the American Society of Anesthesiologists Task Force on Acute Pain Management. *Anesthesiology* 2004;100:1573–1581.
16. **Franklin PD, Karbassi JA, Li W, Yang W, Ayers DC.** Reduction in narcotic use after primary total knee arthroplasty and association with patient pain relief and satisfaction. *J Arthroplasty* 2010;25(Suppl):12–16.
17. **Snyder MA, Scheuerman CM, Gregg JL, Ruhnke CJ, Eten K.** Improving total knee arthroplasty perioperative pain management using a periarticular injection with bupivacaine liposomal suspension. *Arthroplast Today* 2016;2:37–42.
18. **Helmerhorst GTT, Teunis T, Janssen SJ, Ring D.** An epidemic of the use, misuse and overdose of opioids and deaths due to overdose, in the United States and Canada: is Europe next? *Bone Joint J* 2017 Jul;99-B:856–864.
19. **Elmallah RK, Cherian JJ, Pierce TP, et al.** New and common perioperative pain management techniques in total knee arthroplasty. *J Knee Surg* 2016;29:169–178.
20. **Wall PDH, Parsons NR, Parsons H, et al.** A pragmatic randomised controlled trial comparing the efficacy of a femoral nerve block and periarticular infiltration for early pain relief following total knee arthroplasty. *Bone Joint J* 2017;99-B:904–911.
21. **Barrington JW, Olugbode O, Lovald S, et al.** Liposomal bupivacaine: a comparative study of more than 1000 total joint arthroplasty cases. *Orthop Clin North Am* 2015;46:469–477.
22. **Barrington JW, Halaszynski TM, Sinatra RS, Expert Working Group On Anesthesia And Orthopaedics Critical Issues In Hip And Knee Replacement Arthroplasty FT.** Perioperative pain management in hip and knee replacement surgery. *Am J Orthop (Belle Mead NJ)* 2014;43(Suppl):S1–S16.

23. **Cherian J, Muzaffar A, Barrington J, et al.** Liposomal bupivacaine in totalknee arthroplasty for better postoperative analgesic outcome and economic benefits. *J Knee Surg* 2016;29:180–187.
24. **Huang H- T, Su JY, Chang J- K, Chen C- H, Wang G- J.** The early clinical outcome of minimally invasive quadriceps-sparing total knee arthroplasty: report of a 2-year follow-up. *J Arthroplasty* 2007;22:1007–1012.
25. **Saklad M.** Grading of patients for surgical procedures. *Anesthesiol* 1941;2:281–284.
26. **McCormack HM, Horne DJ, Sheather S.** Clinical applications of visual analogue scales: a critical review. *Psychol. Med* 1988;18:1007–1019.
27. **Raut S, Mertes SC, Muniz-Terrera G, Khanduja V.** Factors associated with prolonged length of stay following a total knee replacement in patients aged over 75. *Int Orthop* 2012;36:1601–1608.
28. **Dorr LD, Raya J, Long WT, Boutary M, Sirianni LE.** Multimodal analgesia without parenteral narcotics for total knee arthroplasty. *J Arthroplasty* 2008;23:502–508.
29. **Maheshwari AV, Boutary M, Yun AG, Sirianni LE, Dorr LD.** Multimodal analgesia without routine parenteral narcotics for total hip arthroplasty. *Clin Orthop Relat Res* 2006;453:231–238.
30. **Rathmell JP, Pino CA, Taylor R, Patrin T, Viani BA.** Intrathecal morphine for postoperative analgesia: a randomized, controlled, dose-ranging study after hip and knee arthroplasty. *Anesth Analg* 2003;97:1452–1457.
31. **McGlynn EA.** Introduction and overview of the conceptual framework for a national quality measurement and reporting system. *Med Care* 2003;41(Suppl):I1–I7.
32. **Phillips S, Gift M, Gelot S, Duong M, Tapp H.** Assessing the relationship between the level of pain control and patient satisfaction. *J Pain Res* 2013;6:683–689.
33. **Kirkness CS, Asche CV, Ren J, Kim M, Rainville EC.** Cost-benefit evaluation of liposomal bupivacaine in the management of patients undergoing total knee arthroplasty. *Am J Health Syst Pharm* 2016;73:247–254.
34. **Cien AJ, Penny PC, Horn BJ, Popovich JM, Taunt CJ.** Comparison between liposomal bupivacaine and femoral nerve block in patients undergoing primary total knee arthroplasty. *J Surg Orthop Adv* 2015;24:225–229.
35. **Broome CB, Burnikel B.** Novel strategies to improve early outcomes following total knee arthroplasty: a case control study of intra articular injection versus femoral nerve block. *Int Orthop* 2014;38:2087–2089.
36. **Joshi GP, Cushner FD, Barrington JW, et al.** Techniques for periarticular infiltration with liposomal bupivacaine for the management of pain after hip and knee arthroplasty: a consensus recommendation. *J Surg Orthop Adv* 2015;24:27–35.