J Anesth (2015) 29:471–474
DOI 10.1007/s00540-014-1957-9

SHORT COMMUNICATION

Comparison of catheter tip migration using flexible and stimulating catheters inserted into the adductor canal in a cadaver model

Christopher A. J. Webb · T. Edward Kim · Natasha Funck · Steven K. Howard · T. Kyle Harrison · Toni Ganaway · Heidi Keng · Edward R. Mariano

Received: 24 October 2014 / Accepted: 24 November 2014 / Published online: 16 December 2014

Abstract Use of adductor canal blocks and catheters for perioperative pain management following total knee arthroplasty is becoming increasingly common. However, the optimal equipment, timing of catheter insertion, and catheter dislodgement rate remain unknown. A previous study has suggested, but not proven, that non-tunneled stimulating catheters may be at increased risk for catheter migration and dislodgement after knee manipulation. We designed this follow-up study to directly compare tip migration of two catheter types after knee range of motion exercises. In a male unembalmed human cadaver, 30 catheter insertion trials were randomly assigned to one of two catheter types: flexible or stimulating. All catheters were inserted using an ultrasound-guided short-axis in-plane technique. Intraoperative knee manipulation similar to that performed during surgery was simulated by five sequential range of motion exercises. A blinded regional anesthesiologist performed caliper measurements on the ultrasound images before and after exercise. Changes in catheter tip to nerve distance ($p = 0.547$) and catheter length within the adductor canal ($p = 0.498$) were not different between groups. Therefore, catheter type may not affect the risk of catheter tip migration when placed prior to knee arthroplasty.

Keywords Regional anesthesia · Adductor canal block · Perineural catheter · Total knee arthroplasty · Catheter dislodgement

Congress Presentation(s) Submitted, 40th Annual Regional Anesthesiology and Acute Pain Medicine Meeting and Workshops (Las Vegas, NV, USA, May 14–16, 2015).

C. A. J. Webb · T. E. Kim · N. Funck · S. K. Howard · T. K. Harrison · T. Ganaway · E. R. Mariano
Department of Anesthesiology, Perioperative and Pain Medicine, Stanford University School of Medicine, Stanford, CA, USA

C. A. J. Webb · T. E. Kim · N. Funck · S. K. Howard · T. K. Harrison · H. Keng · E. R. Mariano (✉)
Anesthesiology and Perioperative Care Service, VA Palo Alto Health Care System, 3801 Miranda Avenue (112A), Palo Alto, CA 94304, USA
e-mail: emariano@stanford.edu

Short communication

There is a growing body of evidence in support of the adductor canal block for the perioperative pain management of patients undergoing total knee arthroplasty (TKA) [1–5]. Unlike a femoral nerve catheter (FNC), placement of an adductor canal catheter (ACC) results in selective blockade of the saphenous nerve [6]. Clinically, this translates into less quadriceps muscle weakness and greater early ambulation while providing similar analgesia when compared to FNC [3, 7, 8]. Despite these patient benefits, the optimal timing of placement and catheter equipment remain unknown. For all perineural catheters, there is concern for secondary block failure which is attributed to catheter migration or dislodgement and may be as high as 26 % [9]. When patients undergo TKA, intrinsic to the surgery is intense intraoperative manipulation of the knee that has the potential to affect the final location of ACCs placed preoperatively. A previous study by our group has attempted to assess the extent of ACC tip migration for different types of catheters, tunneled and non-tunneled, using a cadaver model [10]. Although this study failed to demonstrate a difference in catheter tip migration or dislodgement, only the non-tunneled stimulating catheters (2 of 5) were dislodged from the adductor canal after knee manipulation [10]. We therefore designed this follow-up study to test the hypothesis that greater ACC tip migration will occur with stimulating catheters, as compared to flexible catheters, in a cadaver model simulating intraoperative knee manipulation during TKA.

With research committee approval (VA Palo Alto Health Care System, Palo Alto, CA) and IRB exemption, the perioperative conditions of TKA were simulated in an 80-year-old male, 66 kg and 177 cm, unembalmed human cadaver. 30 catheter insertion trials (15 per leg) were randomly assigned using a computer-generated stratified randomization sequence (http://www.randomizer.org) to one of two groups: (1) a flexible epidural catheter (Arrow FlexTip Plus, Teleflex Medical, Research Triangle Park, NC); or (2) a stimulating catheter (Arrow StimuCath, Teleflex Medical, Research Triangle Park, NC).

Using our previously described technique [10], we enhanced the visibility of the flexible epidural catheter by inserting a 3 mm segment of metallic staple (Stanley-Bostitch, East Greenwich, RI) into the distal catheter tip and sealed it with 2-octylcyanoacrylate glue (Dermabond Advanced, Ethicon, Somerville, NJ).

All ACCs were inserted by a single regional anesthesiology fellow using an ultrasound-guided short-axis in-plane technique (Edge, Fujifilm SonoSite, Bothell, WA) [6]. Catheters were inserted at the mid-thigh [5, 6] without the use of hydrodissection. While the catheters were not tunneled, they were secured with a disposable clear transparent dressing (Bioclusive, Systagenix, Gatwick, West Sussex, UK). After the best still ultrasound image demonstrating the catheter tip was acquired and frozen, the ultrasound image was evaluated by an independent expert regional anesthesiologist. The expert was blinded to group assignment and performed caliper measurements (Edge, Fujifilm SonoSite, Bothell, WA), which were verified by a second blinded expert.

To simulate intraoperative patient manipulation during TKA, a second investigator then performed five sequential range of motion (ROM) exercises of the supine cadaver's ipsilateral lower extremity from the knee/leg fully extended (0°) with the heel on the table to hip flexion (90°) and full knee flexion with the sole of the foot flat on the table. The same procedure for image capture and measurements was performed again, for a total of two sets of measurements per catheter insertion trial: one pre-ROM exercise and one post-ROM exercise.

The primary outcome was change in distance (cm) from the catheter tip to the center of the target nerve (Fig. 1), calculated as the difference between baseline pre-ROM exercise distance and post-ROM exercise distance. The secondary outcome was change in length of catheter (cm) within the adductor canal (Fig. 1), measured from the catheter tip to the intersection of the catheter and sartorius fascial plane, calculated as the difference between baseline pre-ROM exercise distance and post-ROM exercise distance.

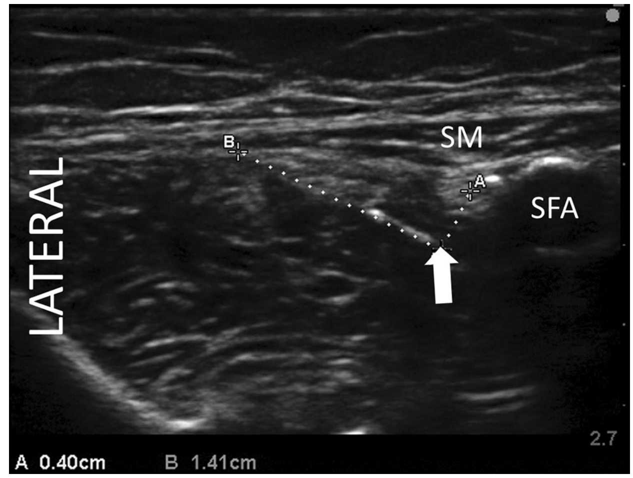

Fig. 1 Sample ultrasound image collected during the study demonstrating the sartorius muscle (*SM*), superficial femoral artery (*SFA*), catheter tip (*white arrow*), center of the target nerve (*A*), and intersection of the catheter and sartorius fascial plane (*B*); catheter tip (*white arrow*) to nerve (*A*) distance and catheter length within the adductor canal (*white arrow* to *B*) were measured in (cm) using the caliper function on the ultrasound machine (Edge, Fujifilm SonoSite, Bothell, WA)

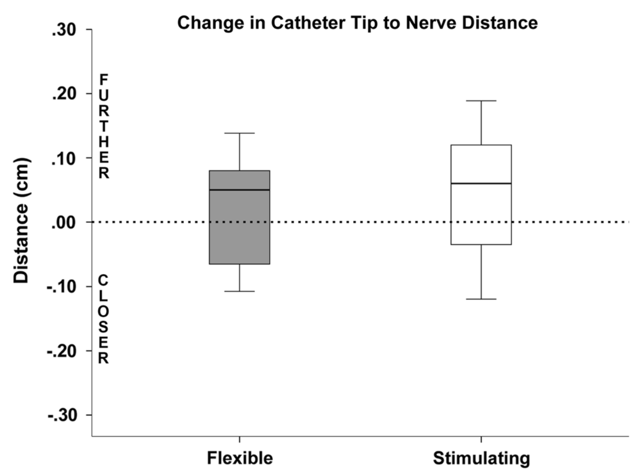

Fig. 2 Change in catheter tip to nerve distance (cm) for the flexible ($n = 15$) and stimulating ($n = 15$) catheter groups; boxes represent 25th–75th percentiles, and whiskers represent 10th–90th percentiles

The sample size was calculated based on the means and standard deviations for non-tunneled flexible and stimulating catheter groups from a previous study [10]: 0.0 ± 0.1 and 0.2 ± 0.2 cm, respectively. We estimated 15 trials per group to detect a statistically-significant difference in the same primary outcome assuming $\alpha = 0.05$ and 80 % power.

Normality of distribution was determined using the Kolmogorov–Smirnov test. Continuous variables of normal distribution were compared using Student's t test; all others were compared using the Mann–Whitney U test.

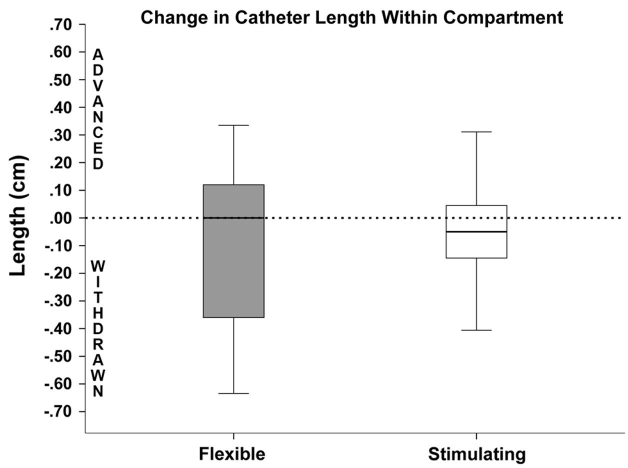

Fig. 3 Change in catheter length within the adductor canal (cm) for the flexible ($n = 15$) and stimulating ($n = 15$) catheter groups; boxes represent 25th–75th percentiles, and whiskers represent 10th–90th percentiles

Differences in proportions were analyzed using the z test or Barnard's exact test. $P < 0.05$ was considered statistically significant.

All 30 catheters were placed successfully on the first attempt; one baseline (pre-ROM) image was unfrozen prior to review and measurement, so the catheter was replaced according to the original group assignment. Changes in catheter tip to nerve distance [median (10th–90th percentiles)] were 0.05 (−0.11 to 0.14) cm for the flexible group and 0.06 (−0.12 to 0.19) cm for the stimulating group ($p = 0.547$). Changes in catheter length within the adductor canal were 0.00 (−0.63 to 0.34) cm for the flexible group and −0.05 (−0.41 to 0.31) cm for the stimulating group ($p = 0.498$; Figs. 2, 3). One of 15 flexible epidural catheters was dislodged out of the adductor canal compared to 0/15 in the stimulating catheter group ($p = 0.525$).

The results of this cadaver study suggest that catheter type may not affect the risk of catheter tip migration for ACC when placed prior to TKA. Further, there was no increased association with dislodgement attributable to catheter type. In our group's previous study, 40 % of the non-tunneled stimulating catheters were dislodged after knee manipulation [10]; while not statistically-significant, this finding as well as the trend toward increased migration with the stimulating catheter required additional study with adequate power given the previous study's small sample size [10].

Lack of difference between the two catheters should not be interpreted as equivalence since the present study was designed for superiority. However, we can conclude that there is no advantage in using one catheter over the other in terms of tip migration. Therefore, anesthesiologists should consider other factors when choosing equipment for ACC. Not all ultrasound-guided perineural catheter insertion techniques are the same, and catheter type is best matched to the technique employed [11, 12]. Although stimulating and non-stimulating catheters have not been studied for ACC, previous studies have shown no benefit in using stimulating catheters for femoral perineural catheters placed with ultrasound [13, 14] or without ultrasound [15, 16]. Cost is another consideration with stimulating catheters being generally more expensive than non-stimulating catheters [17].

There are limitations to the present study. Despite designing the present study based on the previous study's sample size estimate and following the same protocol, there were some differences that may have resulted in Type 2 error. While the same expert regional anesthesiologist served as the primary blinded reviewer and performed all caliper measurements for the present and previous [10] studies, personnel in other roles (e.g., catheter insertion, performance of ROM) differed due to scheduling availability. In addition, the cadaver specimen used, although similar in height and weight, was not the same cadaver from the previous study, so this change may also have influenced our results. The cadaver specimen in the present study was also not obese, and we speculate that body mass index may influence the likelihood of perineural catheter migration. We acknowledge that live human tissues and cadaver tissues do not always respond in the same way [18], and the cadaver model we employed did not reproduce the actual conditions of TKA surgery, factors which may limit the generalizability of our findings. Unfortunately, the echogenicity of commercially available catheters used in regional anesthesia remains limited [19], and the tip of the catheter is difficult to visualize and differentiate from the rest of the catheter without modification [10, 20]. Modification of the catheter as performed in the present study precludes its use in clinical practice, making it impossible to perform the same study in actual patients. Finally, the results of this study are limited to the ultrasound-guided short-axis in-plane technique and catheter equipment described [6, 10]. Other catheter models with varying elasticity [21, 22] or insertion techniques [23, 24], including placement location and course, may generate different results.

In summary, this cadaver study suggests that, for both flexible and stimulating catheters placed preoperatively within the adductor canal, dislodgement rate is low following the simulated intraoperative ROM exercises associated with TKA. Catheter type may not influence migration of the catheter tip away from the target nerve when using an ultrasound-guided short-axis in-plane technique. However, future studies involving other catheter types, alternative insertion techniques, and cadaver specimens of varying body habitus are warranted.

Acknowledgments The authors gratefully acknowledge the assistance of Mr. Russell Sanchez and the Pathology Service, Veterans Affairs Palo Alto Health Care System, Palo Alto, CA, USA.

Conflict of interest Dr. Mariano has received unrestricted educational program funding paid to his institution from I-Flow (Lake Forest, CA, USA) and B Braun (Bethlehem, PA, USA). These companies had absolutely no input into any aspect of the present study conceptualization, design, and implementation; data collection, analysis and interpretation; or manuscript preparation. None of the other authors has any personal financial interests to disclose.

References

1. Hanson NA, Allen CJ, Hostetter LS, Nagy R, Derby RE, Slee AE, Arslan A, Auyong DB. Continuous ultrasound-guided adductor canal block for total knee arthroplasty: a randomized, double-blind trial. Anesth Analg. 2014;118:1370–7.
2. Kim DH, Lin Y, Goytizolo EA, Kahn RL, Maalouf DB, Manohar A, Patt ML, Goon AK, Lee YY, Ma Y, Yadeau JT. Adductor canal block vs femoral nerve block for total knee arthroplasty: a prospective, randomized, controlled trial. Anesthesiology. 2014;120:540–50.
3. Mudumbai SC, Kim TE, Howard SK, Workman JJ, Giori N, Woolson S, Ganaway T, King R, Mariano ER. Continuous adductor canal blocks are superior to continuous femoral nerve blocks in promoting early ambulation after TKA. Clin Orthop Relat Res. 2014;472:1377–83.
4. Mariano ER, Perlas A. Adductor canal block for total knee arthroplasty: the perfect recipe or just one ingredient? Anesthesiology. 2014;120:530–2.
5. Lund J, Jenstrup MT, Jaeger P, Sorensen AM, Dahl JB. Continuous adductor-canal-blockade for adjuvant post-operative analgesia after major knee surgery: preliminary results. Acta Anaesthesiol Scand. 2011;55:14–9.
6. Mariano ER, Kim TE, Wagner MJ, Funck N, Harrison TK, Walters T, Giori N, Woolson S, Ganaway T, Howard SK. A randomized comparison of proximal and distal ultrasound-guided adductor canal catheter insertion sites for knee arthroplasty. J Ultrasound Med. 2014;33:1653–62.
7. Jaeger P, Zaric D, Fomsgaard JS, Hilsted KL, Bjerregaard J, Gyrn J, Mathiesen O, Larsen TK, Dahl JB. Adductor canal block vs femoral nerve block for analgesia after total knee arthroplasty: a randomized, double-blind study. Reg Anesth Pain Med. 2013;38:526–32.
8. Shah NA, Jain NP. Is continuous adductor canal block better than continuous femoral nerve block after total knee arthroplasty? Effect on ambulation ability, early functional recovery and pain control: a randomized controlled trial. J Arthroplasty. 2014 (Epub ahead of print).
9. Ahsan ZS, Carvalho B, Yao J. Incidence of failure of continuous peripheral nerve catheters for postoperative analgesia in upper extremity surgery. J Hand Surg Am. 2014;39:324–9.
10. Leng JC, Harrison TK, Miller B, Howard SK, Conroy M, Udani A, Shum C, Mariano ER. A pilot study to assess adductor canal catheter tip migration in a cadaver model. J Anesth 2014 (Epub ahead of print).
11. Ilfeld BM. Continuous peripheral nerve blocks: a review of the published evidence. Anesth Analg. 2011;113:904–25.
12. Ilfeld BM, Fredrickson MJ, Mariano ER. Ultrasound-guided perineural catheter insertion: three approaches but few illuminating data. Reg Anesth Pain Med. 2010;35:123–6.
13. Gandhi K, Lindenmuth DM, Hadzic A, Xu D, Patel VS, Maliakal TJ, Gadsden JC. The effect of stimulating vs conventional perineural catheters on postoperative analgesia following ultrasound-guided femoral nerve localization. J Clin Anesth. 2011;23:626–31.
14. Farag E, Atim A, Ghosh R, Bauer M, Sreenivasalu T, Kot M, Kurz A, Dalton JE, Mascha EJ, Mounir-Soliman L, Zaky S, Ali Sakr Esa W, Udeh BL, Barsoum W, Sessler DI. Comparison of three techniques for ultrasound-guided femoral nerve catheter insertion: a randomized, blinded trial. Anesthesiology. 2014;121:239–48.
15. Hayek SM, Ritchey RM, Sessler D, Helfand R, Samuel S, Xu M, Beven M, Bourdakos D, Barsoum W, Brooks P. Continuous femoral nerve analgesia after unilateral total knee arthroplasty: stimulating vs nonstimulating catheters. Anesth Analg. 2006;103:1565–70.
16. Morin AM, Eberhart LH, Behnke HK, Wagner S, Koch T, Wolf U, Nau W, Kill C, Geldner G, Wulf H. Does femoral nerve catheter placement with stimulating catheters improve effective placement? A randomized, controlled, and observer-blinded trial. Anesth Analg. 2005;100:1503–10.
17. Sandhu NS, Sidhu DS, Capan LM. The cost comparison of infraclavicular brachial plexus block by nerve stimulator and ultrasound guidance. Anesth Analg. 2004;98:267–8.
18. Symons B, Wuest S, Leonard T, Herzog W. Biomechanical characterization of cervical spinal manipulation in living subjects and cadavers. J Electromyogr Kinesiol. 2012;22:747–51.
19. Mariano ER, Yun RD, Kim TE, Carvalho B. Application of echogenic technology for catheters used in ultrasound-guided continuous peripheral nerve blocks. J Ultrasound Med. 2014;33:905–11.
20. Kan JM, Harrison TK, Kim TE, Howard SK, Kou A, Mariano ER. An in vitro study to evaluate the utility of the "air test" to infer perineural catheter tip location. J Ultrasound Med. 2013;32:529–33.
21. Grant SA, Nielsen KC, Greengrass RA, Steele SM, Klein SM. Continuous peripheral nerve block for ambulatory surgery. Reg Anesth Pain Med. 2001;26:209–14.
22. Ip VH, Tsui BC. The catheter-over-needle assembly facilitates delivery of a second local anesthetic bolus to prolong supraclavicular brachial plexus block without time-consuming catheterization steps: a randomized controlled study. Can J Anaesth. 2013;60:692–9.
23. Mariano ER, Kim TE, Funck N, Walters T, Wagner MJ, Harrison TK, Giori N, Woolson S, Ganaway T, Howard SK. A randomized comparison of long-and short-axis imaging for in-plane ultrasound-guided femoral perineural catheter insertion. J Ultrasound Med. 2013;32:149–56.
24. Tsui BC, Ozelsel TJ. Ultrasound-guided anterior sciatic nerve block using a longitudinal approach: "expanding the view". Reg Anesth Pain Med. 2008;33:275–6.