J Anesth (2015) 29:308–312
DOI 10.1007/s00540-014-1922-7

SHORT COMMUNICATION

A pilot study to assess adductor canal catheter tip migration in a cadaver model

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Received: 10 January 2014 / Accepted: 9 September 2014 / Published online: 7 October 2014

Abstract An adductor canal catheter may facilitate early ambulation after total knee arthroplasty, but there is concern over preoperative placement since intraoperative migration of catheters may occur from surgical manipulation and result in ineffective analgesia. We hypothesized that catheter type and subcutaneous tunneling may influence tip migration for preoperatively inserted adductor canal catheters. In a male unembalmed human cadaver, 20 catheter insertion trials were divided randomly into one of four groups: flexible epidural catheter either tunneled or not tunneled; or rigid stimulating catheter either tunneled or not tunneled. Intraoperative patient manipulation was simulated by five range-of-motion exercises of the knee. Distance and length measurements were performed by a blinded regional anesthesiologist. Changes in catheter tip to nerve distance ($p = 0.225$) and length of catheter within the adductor canal ($p = 0.467$) were not different between the four groups. Two of five non-tunneled stimulating catheters (40 %) were dislodged compared to 0/5 in all other groups ($p = 0.187$). A cadaver model may be useful for assessing migration of regional anesthesia catheters; catheter type and subcutaneous tunneling may not affect migration of adductor canal catheters based on this preliminary study. However, future studies involving a larger sample size, actual patients, and other catheter types are warranted.

Keywords Regional anesthesia · Adductor canal block · Continuous peripheral nerve block · Total knee arthroplasty · Catheter dislodgement

The adductor canal catheter (ACC) is becoming increasingly utilized as the continuous peripheral nerve block of choice for postoperative pain control after total knee arthroplasty (TKA). The ACC is more selective than the femoral nerve catheter (FNC), targeting the saphenous nerve distally; since the saphenous nerve is a sensory branch, patients with an ACC maintain quadriceps strength to ambulate earlier after TKA [1] with similar postoperative pain scores and opioid consumption when compared to FNC [2]. Many of the recent studies evaluating the beneficial effects of ACCs for TKA describe either post-surgical placement of nerve blocks [3–5], or placement of blocks in non-operative volunteers [6, 7]. However, in clinical practice, preoperative insertion may offer certain advantages. Performing peripheral nerve blocks preoperatively, when compared with general anesthesia or intraoperatively administered local anesthetics, improves operating room efficiency in some settings [8, 9]. In addition, preoperative ACC insertion may be preferred for the purpose of block

Congress presentations: 39th Annual regional anesthesiology and acute pain medicine meeting and workshops, (Chicago, IL, USA, April 3–6, 2014).

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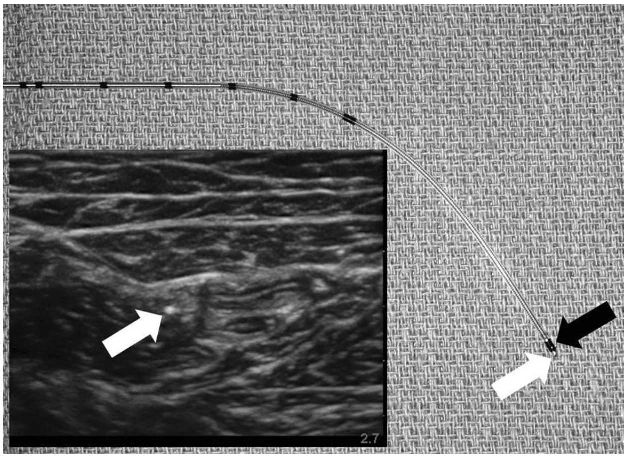

Fig. 1 Flexible epidural catheter modified to enhance echogenicity with actual sonogram demonstrating echogenicity of the catheter tip; *black arrow*: actual catheter tip; *white arrow*: modified tip with metallic insert

assessment before induction for patients undergoing general anesthesia or onset of spinal anesthesia. However, the postoperative efficacy of preoperatively placed ACCs has not yet been specifically evaluated. Since the knee undergoes intraoperative manipulation, there is concern that these catheters are at risk of migration away from the saphenous nerve or even dislodgement out of the adductor canal. For this initial investigation, we designed a pilot 2 × 2 factorial study using a cadaver model to test the hypothesis that catheter type and subcutaneous tunneling affect catheter tip migration for preoperatively inserted ACCs.

With research committee approval (VA Palo Alto Health Care System, Palo Alto, CA, USA) and IRB exemption, the perioperative conditions of TKA were simulated in a male, 60 kg and 173 cm, unembalmed human cadaver. Twenty catheter insertion trials included in a convenience sample were randomly assigned using a computer-generated stratified randomization sequence (www.random.org) to one of four groups: (1) a tunneled flexible catheter (Arrow FlexTip Plus, Teleflex Medical, Research Triangle Park, NC, USA); (2) a tunneled rigid stimulating catheter (Arrow StimuCath, Teleflex Medical, Research Triangle Park, NC, USA); (3) the same flexible epidural catheter not tunneled; or (4) the same rigid stimulating catheter not tunneled.

In preparation for this study, the rigid stimulating catheter tip was determined to be identifiable by ultrasound in a porcine meat model described previously [10]. The flexible epidural catheter required slight modification to enhance tip visibility; therefore, a short 3-mm segment of metallic staple (Stanley-Bostitch, East Greenwich, RI, USA) was inserted into the distal catheter tip and sealed with 2-octylcyanoacrylate glue (Dermabond Advanced, Ethicon, Somerville, NJ, USA) (Fig. 1).

Using the previously described mid-thigh approach [3], all ACCs were inserted by a single regional anesthesiology fellow using an ultrasound-guided short-axis, in-plane technique (M-Turbo, Fujifilm SonoSite, Bothell, WA, USA) without injecting fluid through the placement needle. If assigned to a tunneled group, the catheter was then tunneled subcutaneously in a cephalad and lateral direction toward the ipsilateral iliac crest. Each catheter was secured with a single-use transparent dressing (Bioclusive, Systagenix, Gatwick, West Sussex, UK). After determining the best still ultrasound image demonstrating the catheter tip, the image was frozen and the ultrasound machine was delivered to an independent expert regional anesthesiologist, blinded to group assignment, to perform caliper measurements (M-Turbo, Fujifilm SonoSite, Bothell, WA, USA) with secondary real-time confirmation 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 and one post-ROM.

The primary outcome was change in distance (cm) from the catheter tip to the center of the target nerve, calculated as the difference between baseline pre-ROM distance and post-ROM distance. The secondary outcome was change in length of catheter (cm) within the adductor canal, measured from the catheter tip to the intersection of the catheter and sartorius fascial plane, calculated as the difference between baseline pre-ROM distance and post-ROM distance. Distance and length measurements were compared using analysis of variance with Tukey–Kramer post hoc testing for multiple comparisons. Differences in proportions were compared using the z test or Barnard's exact test. $p < 0.05$ was considered statistically significant.

All 20 catheters were placed successfully on the first attempt; one catheter was inadvertently dislodged prior to freezing the image and was replaced according to the original group assignment since measurements had not yet been taken or recorded. Changes in catheter tip to nerve distance ($p = 0.225$) and change in catheter length within the adductor canal ($p = 0.467$) were not different between any of the four groups (Figs. 2, 3, respectively). Two out of five non-tunneled rigid stimulating catheters were withdrawn out of the adductor canal compared to 0/5 in all other groups ($p = 0.187$ for group 4 vs. 1).

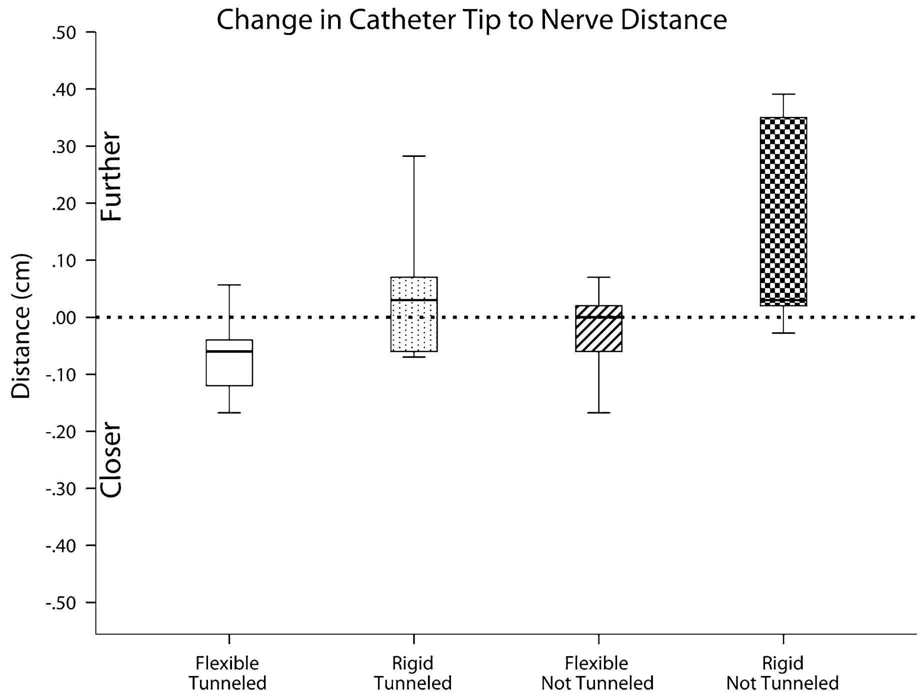

Fig. 2 Change in catheter tip to nerve distance (cm)

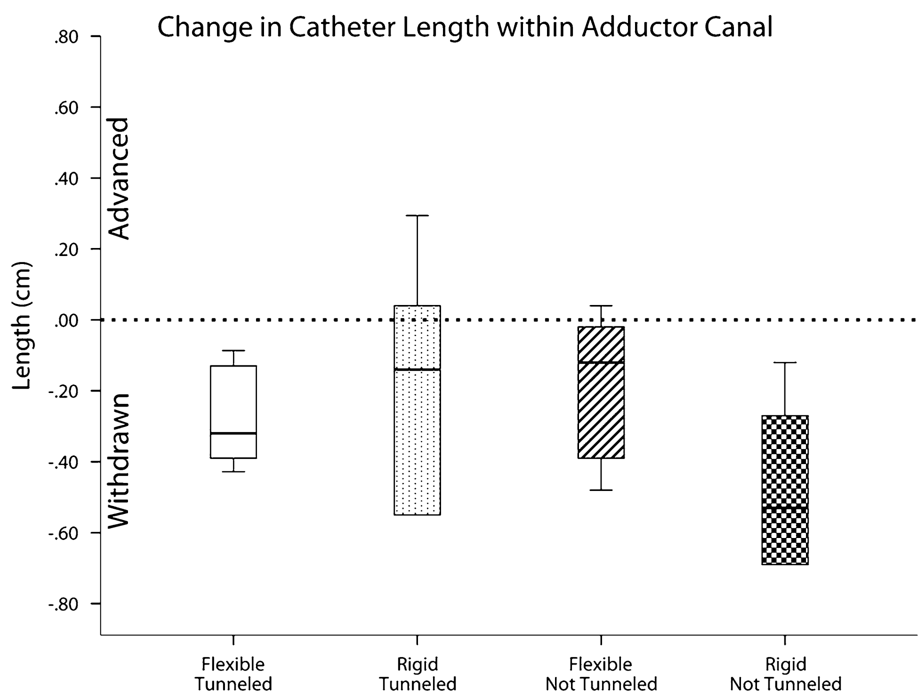

Fig. 3 Change in catheter length within the adductor canal (cm)

The results of this cadaver-based pilot study show that neither catheter type nor subcutaneous tunneling have an effect on migration of catheters within the adductor canal. However, 40 % of non-tunneled rigid stimulating catheters were dislodged post-ROM compared to none in the other groups. Although this result was not statistically significant, the negative finding may be attributable to type 2 error and deserves further investigation with a follow-up study involving a larger sample. Since perineural catheters are affixed to the skin after placement, a more rigid catheter may theoretically be at higher risk of translating external movement of the thigh to internal migration of the catheter tip. The proper selection of catheter equipment for ultrasound-guided continuous peripheral nerve block is a crucial issue and depends on the ultrasound technique used [11]. When using a short-axis in-plane technique, we speculate that tunneling the rigid stimulating catheter may have minimized changes in catheter tip-to-nerve distance and catheter length, making the lack of migration similar to the two flexible catheter groups. Further, tunneling the flexible epidural-type catheter did not influence catheter movement. Given these findings, tunneling a flexible catheter may not be necessary to prevent catheter migration, which may potentially decrease total procedural time and improve efficiency.

This cadaver study has important limitations, including the potential differences in tissue mechanics between cadavers and actual patients [12], and the lack of clinical outcome data. We do not know if catheter movement in a cadaver, although not embalmed, is identical to what can be expected in a patient. However, the ability to directly visualize the actual perineural catheter tip in patients with ultrasound remains difficult [11], and regional anesthesiologists typically resort to methods that infer catheter location such as the "air test", which precludes the ability to measure catheter tip-to-target nerve distance [10]. In addition, although intraoperative lower-extremity manipulation was simulated, a thigh tourniquet, not included in the present study's protocol, is commonly utilized during TKA surgery and may influence catheter movement. Finally, the negative results in the present study may be attributable to type 2 error, and a larger sample size may have demonstrated statistically significant differences in migration and dislodgement of the rigid non-tunneled catheter. This is purely speculative at this point and requires further study. A post hoc sample size calculation using the means and standard deviations for the non-tunneled flexible and stimulating catheter groups (0.0 ± 0.1 and 0.2 ± 0.2 cm, respectively) estimates 15 trials per group will be required for a future study to detect a statistically significant difference in the same primary outcome between these groups assuming $\alpha = 0.05$ and 80 % power. For cadaver-based research involving regional anesthesia, it is not uncommon to employ a convenience sample based on the unpredictable availability of specimens [13–15]. Since the number of trials on a single cadaver would be limited, we attempted to minimize variability by standardizing as many aspects of the study protocol as possible (e.g., one investigator placing all catheters, one investigator performing all ROM exercises, and one investigator conducting all measurements).

In summary, catheter type and tunneling may not affect migration of preoperatively inserted ACCs based on this limited pilot study, but our results suggest a trend toward increased dislodgement when using a non-tunneled stimulating catheter. The present study does validate the utility of a cadaver model with a modified catheter tip that is visible sonographically to facilitate dynamic evaluation of indwelling regional anesthesia catheters without injection of dye. Future studies involving a larger sample size, live subjects if feasible, and other catheter types 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.

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