Use of a stimulating catheter for total knee replacement surgery: preliminary results

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Background. There is continuing debate as to whether the use of electrical stimulation that aids in localizing nerves is also beneficial for optimizing placement of nerve catheters and lead to improved clinical outcomes, such as reductions in pain scores and opioid consumption.

Methods. We undertook a retrospective, non-randomized comparison of stimulating and non-stimulating nerve catheters in 419 patients undergoing total knee replacement between December 2002 and July 2004. Before surgery, patients received sciatic and femoral nerve blocks with a catheter for the femoral nerve. In 159 patients a stimulating catheter system (Stimucath; Arrow International, Reading, PA, USA) and in 260 patients a non-stimulating catheter system (Contiplex; B. Braun, Melsungen, Germany) was used. After surgery, pain scores and morphine consumption were recorded at 4-h intervals until the first postoperative morning. In a subset of 85 patients, the postoperative evaluation period was lengthened to 3 days.

Results. Postoperative visual analogue scores (VAS) for pain were similar in the two groups during the first 24 h (P=0.305). In patients followed for 3 days, VAS scores did not differ on any of the days (P=0.427). Total morphine consumption did not differ on the first postoperative day (mean [95% CI]: stimulating, 12.4 [10.1–14.7] mg; non-stimulating 10.4 [8.9–11.8] mg; P=0.140) or on subsequent days.

Conclusions. The practical advantages of the stimulating catheter, as reported by previous investigators, were not obvious in this clinical situation. In terms of outcome measures such as pain scores and morphine consumption, we found no significant differences between stimulating and non-stimulating catheters.

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Peripheral nerve localization using electrical stimulation via insulated needles has become a widespread practice in regional anaesthesia. The use of continuous peripheral nerve catheters inserted through these same needles is a relatively new technique, used to provide an extended period of analgesia after surgery. There is continuing debate as to whether the use of the same electrical stimulation that aids in localizing specific nerves is also beneficial for optimizing placement of nerve catheters and will lead to measurable improvements in clinical outcomes, such as reductions in pain scores and opioid consumption.

For example, in a prospective, randomized, double-blinded study,1 bilateral femoral catheters were placed in 20 volunteers. A stimulating catheter was placed on one side and an identical non-stimulating catheter on the contralateral side. There was an increased success rate (defined as loss of sensation to cold and pinprick stimuli, 100% for stimulating catheter vs 85% for non-stimulating catheter), better tolerance to transcutaneous electrical stimulation, and greater depth of motor block when continuous stimulation was used during placement of the catheters. The logical conclusion from this finding is that the ability to electrostimulate
nerves using *in situ* catheters increases the accuracy of catheter placements, which could translate to improved clinical outcomes.

Pham-Dang and colleagues\(^2\) came to a similar conclusion. In their clinical study, the incidence of failed block was 0% when stimulating catheters were used for a variety of peripheral nerve infusions. However, these authors\(^2\) also reported that they were unable to obtain any stimulation through the catheter in nearly 5% of all the patients, which would bring the overall failure rate closer to that of non-stimulating catheters. Furthermore, infusions were successful in some patients despite failure to obtain stimulation through the catheter, indicating that the absence of stimulation may not necessarily mean that placement of a peripheral nerve catheter failed.

Obviously, clinicians prefer to use techniques that have higher success rates. Thus, the use of a stimulating catheter rather than a non-stimulating catheter would seem preferable. However, if success rates of the analgesic peripheral nerve infusions are defined in terms of postoperative visual analogue pain scores or the need for additional opioid consumption, there is an abundance of literature demonstrating high success rates with non-stimulating catheters.\(^3-6\) In terms of these clinical outcome measures, the extra value of the stimulating catheter has yet to be demonstrated in actual clinical practice. Is the additional time, effort, and money required, as well as the discomfort to the patient from multiple needle manipulations, worth placing a stimulating catheter in every patient receiving regional anaesthesia?

We present the results from a retrospective, non-randomized clinical comparison of stimulating and non-stimulating femoral nerve catheters used for total knee replacement operations. Prior to the data collection, we hypothesized that patients receiving the stimulating catheter would have lower postoperative pain scores and morphine consumption than those receiving the non-stimulating catheter.

**Methods**

Participating patients were treated at the St Maarten’s specialized orthopaedic clinic in Nijmegen, The Netherlands. All patients scheduled for total knee replacement surgery from 28 November 2002 until 1 July 2004 and consenting to a peripheral nerve block technique were included in the study (*n*=419). A small number of patients were excluded: those insisting on remaining awake during the procedure were given a spinal anaesthetic, and those refusing any form of regional anaesthesia were given a general anaesthetic.

The institutional review board at this facility approved the review of hospital charts and databases. The same team of four consultant surgeons performed all operations. There were no changes in surgical technique or protocols for the total knee arthroplasty during the study period. A team of five consultant anaesthesiologists, all with extensive experience in peripheral nerve block techniques using nerve stimulation, conducted the anaesthetic management.

**Protocol**

None of the patients scheduled for total knee replacement surgery had been prescribed preoperative opioid analgesics. Premedication was not given unless requested by the patient. In such cases midazolam 7.5 mg was given orally on the morning of surgery. Routine anaesthetic safety monitors were applied in the preparation rooms.

Before surgery, all patients received a sciatic and femoral nerve block (combined block), with a catheter for the femoral nerve only. The single-shot sciatic nerve block was carried out using the landmarks described by Labat and modified by Winnie and colleagues,\(^7\) using a HNS 11 electrical nerve stimulator and a 21 G, 100 mm insulated needle (Stimuplex A, B. Braun, Melsungen, Germany). For the sciatic nerve, a threshold value <0.3 mA at 0.1 ms was sought. In both groups, ropivacaine 0.75%, 20 ml was injected for the sciatic nerve blocks. The femoral nerve block was carried out at the level of the inguinal crease as described by Vloka and colleagues,\(^8\) using a nerve stimulation technique. A threshold of <0.5 mA at 0.1 ms was sought for the femoral nerve block for the initial nerve localization with the insulated needle from either the stimulating (Stimucath; Arrow International, Reading, PA, USA) or the non-stimulating system (Contiplex; B. Braun).

In 260 patients, a femoral nerve catheter (Contiplex) was advanced without catheter-guided stimulation for a distance of 3–5 cm into the femoral nerve sheath after an initial bolus of ropivacaine 0.75%, 40 ml through the needle. Placement of the non-stimulating catheter was always simple, and the catheter was placed at the first attempt.

In 159 other patients, the femoral nerve catheter was placed with guidance by nerve stimulation (Stimucath). No prior injection of local anaesthetic or normal saline was made before advancing the stimulating catheter. Stimulation was continued during introduction of the catheter. In our experience, the stimulating catheter often required multiple repositioning attempts before acceptable values were achieved. Unlike other investigators,\(^2\) we did not regularly observe unusually high values of stimulation current through the catheter. In our series, it was always possible to achieve stimulation at 0.1 ms and <1 mA. However, achieving a low stimulating value through the needle may not be essential; in order to get good stimulation through the catheter it is often necessary to withdraw the needle slightly before introducing the catheter. In other words, suboptimal placement of the needle (by electrical criteria) is often necessary in order to gain optimal placement of the catheter. Quadriceps contractions with a stimulating current of ≈1 mA at 0.1 ms were considered adequate for final placement. One milliampere was chosen as an acceptable value on the recommendation of the manufacturer because the extra placement attempts needed to achieve lower values might lead to nerve damage.
In many cases lower values were achieved at the first placement attempt, and these were accepted. A bolus of ropivacaine 0.75%, 40 ml was administered through the stimulating catheter after placement.

Routine anaesthetic safety monitoring was continued in the operating room with non-invasive blood pressure measurements, continuous oxygen saturation measurement, and continuous electrocardiography. General anaesthesia with a laryngeal mask, using propofol and alfentanil infusions, was used in 18% of cases with the stimulating catheter, and 21% of cases with the non-stimulating catheter. The remainder of the patients (82% of stimulating catheter cases and 79% of non-stimulating catheter cases) all received sedation with propofol and alfentanil infusions during the operation. Administration of both drugs was stopped at the end of the operation. The dose of alfentanil was titrated to a respiratory rate of 10–12 bpm, and varied between 0.5 and 2.0 mg h\(^{-1}\). No additional intraoperative analgesics were given other than the alfentanil infusions. All medication infusions were stopped before the end of surgery.

After the operation, patients remained in the post anaesthesia care unit (PACU) until the following morning. Pain scores and morphine consumption were recorded at 4-h intervals until 06:00 h on the first postoperative morning. Verbal analogue scale (VAS) scores for pain on a scale of 0–10 and morphine consumption were recorded every 4 h. Ropivacaine 0.2% was administered as an additional 20-ml bolus if a VAS score >3 was reported, provided that 6 h had passed since the previous injection. A morphine patient controlled analgesia (PCA) pump was given to patients only if the VAS score remained >3 despite additional ropivacaine boluses. When a PCA pump was used, the settings were standardized: 1-mg boluses and a lockout time of 5 min (total limit 12 mg h\(^{-1}\)). After April 2004, the evaluation period was lengthened to 3 days after surgery, and these results (VAS scores recorded twice daily) are also presented (a subset of 85 from the total of 419 patients: 21 stimulating and 64 non-stimulating catheters).

**Data analysis**

Demographic and morphometric data for the patients were compared using unpaired two-tailed \(t\) tests. Male/female ratios and use of general anaesthesia were analysed using the \(\chi^2\)-test. The VAS scores at different time points were compared between the two groups using repeated measures analysis of variance (ANOVA). The total morphine and total ropivacaine consumption were compared between the two groups using unpaired two-tailed \(t\)-tests. Age, weight, VAS scores, ropivacaine and morphine consumption are presented as mean [95\% confidence interval]; \(P<0.05\) was considered statistically significant.

**Results**

Overall, weight and gender distribution were similar in the two groups (Table 1); however, the patients in the stimulating catheter group (64 [63–66] yr) were older than those in the non-stimulating catheter group (62 [61–63] yr; \(P=0.040\)). Weight, gender, and age distribution (data not shown) were also similar between the groups in the subset of 85 patients evaluated after April 2004 who were followed for 3 days after surgery. There was no significant difference in the use of general anaesthesia between groups (stimulating and non-stimulating: 18 and 21\%, respectively; \(P=0.377\)). Pain scores were similar in the two groups at all times during the first 24 h (Fig. 1; \(P=0.305\)). The study had 95\% power to detect a difference in VAS values as low as 1 for the first day (Fig. 1). In the subgroup of patients followed for 3 days after surgery (21 with stimulating and 64 with non-stimulating catheters), VAS scores did not differ on any of the days (Fig. 2; \(P=0.427\)). There was 90\% power to detect a difference in VAS values of 2 in the subset of 85 patients who were followed for 3 days (Fig. 2).

Total morphine consumption did not differ in the two groups by 06:00 h on the first postoperative day or on the 2 subsequent days (Table 2). The study achieved 90\% power to detect a difference of at least 4 mg in daily morphine consumption between groups, using an unpaired \(t\)-test with \(\alpha=0.05\). In addition, total ropivacaine consumption was similar in the groups at 06:00 h on the first postoperative day (stimulating, 43 [18] ml; non-stimulating, 49 [15] ml; \(P=0.13\)).

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**Table 1** Demographic and morphometric data. Age and weight are presented as means [95\% confidence intervals]. Age and weight comparisons were made with unpaired two-tailed \(t\)-tests, and men/women comparisons with \(\chi^2\)-tests.

<table>
<thead>
<tr>
<th></th>
<th>Stimulating</th>
<th>Non-stimulating</th>
<th>(P)-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>159</td>
<td>260</td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>64 [63–66]</td>
<td>62 [61–63]</td>
<td>0.040</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>84.0 [81.5–86.4]</td>
<td>83.0 [81.3–84.7]</td>
<td>0.350</td>
</tr>
<tr>
<td>Men/women (ratio)</td>
<td>50/109 (0.46)</td>
<td>82/178 (0.46)</td>
<td>0.984</td>
</tr>
</tbody>
</table>

**Fig 1** VAS scores \((n=419)\) until the morning (06:00 h) after operation. Data are means with 95\% confidence intervals. Comparisons were made using repeated measures ANOVA \((P=0.305)\). Closed squares represent data from patients receiving stimulating electrodes; open squares represent those receiving non-stimulating electrodes.
and experienced in placing non-stimulating femoral nerve catheters. One anaesthetist did not use the stimulating catheter, whilst the remaining four anaesthetists used it until the results of the study became clear. Reviewing the data for these four individual anaesthetists did not alter the final conclusions of this study (data not shown). Thus, the absence of randomization, although a significant weakness, is unlikely to nullify the validity of the study.

Another criticism may be that it is unrealistic to compare the two catheter systems during the first 24 h as the initial block will remain at least partially effective during this period. However, this criticism is not entirely valid; based on our own previous experience, pain scores are significantly lower when 6-hourly boluses of ropivacaine are given through the femoral catheter in the first 24 h than when boluses are either not given or given only as needed. Thus, the catheters have a measurable effect and comparison is possible even in the first 24 h. Additionally, there was no significant difference in pain scores or morphine consumption between the patients receiving stimulating or non-stimulating catheters in the subset of patients followed for 3 postoperative days. The only suggestion that the stimulating catheters might perform better is the fact that these patients needed slightly less morphine on the first postoperative day. This difference approaches statistical significance, and it is possible that with more patients a statistically significant difference might have been detected, but it is doubtful that even then the difference would be clinically relevant.

The possibility that the intraoperative alfentanil infusions may have had an influence on the postoperative pain cannot be entirely excluded. However, the low dose used (between 0.5 and 2.0 mg h\(^{-1}\)) and the pharmacokinetic profile of the drug\(^5\) make this unlikely. The total amount of alfentanil used during the operation was not registered in the database, so the two groups cannot be compared in this respect.

This study does not attempt to demonstrate that the placement of the non-stimulating catheter is as accurate as that of the stimulating catheter; what it does show clearly is that, in experienced hands using the techniques described above, the results obtained using a non-stimulating catheter may be excellent and nearly equivalent clinically to those achieved with a stimulating one. It seems paradoxical that, despite the fact that stimulating catheters seem to offer more accurate placement,\(^1\) it has yet to be demonstrated that they cause significant improvements in clinical outcome measures such as pain scores and opioid consumption.

One could speculate that the close approximation to the nerves to the degree that is afforded by the use of stimulating catheters is perhaps unnecessary. We share the view of Salinas and colleagues\(^1\) that close approximation of the catheter tip to the nerve should allow smaller volumes. It may well be that the stimulating catheter will perform better at lower bolus volumes or at lower infusion rates, whereas a larger bolus will reach the nerve even when catheter localization is less accurate. The decision to use local

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**Discussion**

The practical advantages of the stimulating catheter, which were confirmed by Salinas and colleagues\(^1\) and Pham-Dang and colleagues\(^2\) and were expected in our study, were not obvious in this clinical situation. Our results may simply reflect the difference in measured outcomes. In our opinion, it is difficult to measure objectively how successful a block is in clinical situations. Loss of temperature and pinprick sensation does not always correlate well with the patient’s reaction to surgical stimuli. Because of this difficulty in assessing block quality, we used postoperative morphine consumption and pain scores as clinically relevant measures of success. In terms of these outcome measures, we found no significant differences between stimulating and non-stimulating catheters. The study had adequate power to detect a difference in daily morphine consumption of at least 4 mg. We do not regard differences in daily morphine consumption of ≤4 mg as clinically relevant in this population. In addition, the study had adequate power to detect a difference in VAS values as low as 1 for the first day, and as low as 2 in the subset of patients followed for 3 days.

One major drawback of our study is the lack of randomization. At the commencement of the study period, the stimulating catheters were not available in the St Maartenskliniek. The stimulating catheters were introduced later, by which time all participating anaesthetists were competent

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**Table 2**

Average morphine consumption (mg) over 3 days. Data are mean [95% confidence interval]. Comparisons between the two groups were made using unpaired two-tailed t tests. *All patients (n=419); *subset of patients (n=85)

<table>
<thead>
<tr>
<th>Day</th>
<th>Stimulating</th>
<th>Non-stimulating</th>
<th>P-value</th>
</tr>
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<tbody>
<tr>
<td>Day 1*</td>
<td>12.4 [10.1–14.7]</td>
<td>10.4 [8.9–11.8]</td>
<td>0.140</td>
</tr>
<tr>
<td>Day 2*</td>
<td>8.0 [4.0–11.9]</td>
<td>8.1 [5.4–10.9]</td>
<td>0.944</td>
</tr>
<tr>
<td>Day 3*</td>
<td>3.2 [0.8–6.0]</td>
<td>2.3 [0.6–3.8]</td>
<td>0.568</td>
</tr>
</tbody>
</table>

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**Fig 2** VAS scores on the first 3 days after surgery in a subset of patients (n=85). Pain scores were collected at 08:00 h (VAS 1) and 21:00 h (VAS 2). Data are means with 95% confidence intervals. Comparisons were made with repeated measures ANOVA (P=0.427). Closed squares represent data from patients receiving stimulating electrodes; open squares represent those receiving non-stimulating electrodes.

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**Stimulating vs non-stimulating catheters**

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anaesthetic boluses instead of a continuous infusion for this study was an arbitrary one. However, the toxicity of the local anaesthetic in such low concentrations is clinically negligible, and it has not been shown that continuous infusions produce better clinical results.

It is conceivable that clinicians with less experience might find that the ability to verify accuracy of catheter placement with the stimulating catheter system improves their clinical outcomes. However the introduction of the stimulating catheter requires more expertise than introduction of the non-stimulating catheter. As mentioned above, placing the catheter to give good contractions often involves extra manipulation, reintroduction of the needle, or both. Thus, the authors would not (necessarily) expect the stimulating catheter to give better results in inexperienced hands.

Considering the ease of placement and low cost of non-stimulating catheters, a convincing argument has yet to be made for the routine use of the stimulating catheter for continuous femoral nerve block. Further prospective randomized clinical studies are planned that will allow us to reach more definitive conclusions.

Acknowledgement
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References
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