Cost-effectiveness of ultrasound vs nerve stimulation guidance for continuous sciatic nerve block†

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Editor’s key points
- This study analysed the cost-effectiveness of ultrasound (US) vs nerve stimulation (NS) guidance for continuous peripheral sciatic nerve block after major foot and ankle surgery.
- US-guided continuous sciatic block is highly cost-effective, being cheaper in ~84.7% of the cases than NS.
- The success rate was significantly improved with US compared with NS-guided block.

Background. This study assessed the cost-effectiveness of ultrasound (US) vs nerve stimulation (NS) guidance for continuous sciatic nerve block in Danish elective patients undergoing major foot and ankle surgery.

Methods. A cost-effectiveness analysis was conducted alongside a randomized controlled trial. A total of 100 consecutive patients were randomly assigned to either traditional electrical NS or US technique for catheter insertion guidance. Information on effects and costs were collected prospectively. An incremental cost-effectiveness ratio (ICER) was calculated as the extra cost per extra successful nerve block. The robustness of the ICER was investigated using 4000 non-parametric bias-corrected bootstrap replicates to calculate the likelihood that US leads to better effect and lower costs compared with NS guidance.

Results. The mean ICER was negative, indicating that US was a dominating technology providing both higher quality and lower costs. The likelihood of US being more effective and cheaper than NS was estimated to 84.7%.

Conclusions. In this trial, US was cost-effective. Assuming that the results are fairly generalizable, US should be the preferred catheter insertion technique in larger anaesthesia departments.

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Pain after major foot and ankle surgery is usually severe and patients benefit from continuous sciatic nerve block with a catheter technique.1 2 Ultrasound (US) guidance improves the success rate (SR) of postoperative continuous sciatic nerve block compared with electrical nerve stimulation (NS) technique.2 From a health economic point of view, a higher SR is, however, not sufficient for the implementation of US as the first-choice procedure for nerve localization and catheter guidance. The technique should also be acceptable to patients, and if publicly funded, the use of scarce resources in healthcare should represent ‘good value for money’. That is, the decision to implement US should be based on solid evidence of clinical health outcomes and cost-effectiveness.

Previous studies addressing the economic issues of US vs NS for peripheral nerve blocks3–5 have estimated that the higher acquisition costs of US equipment are counterbalanced by the possible savings with US guidance due to increased efficacy of nerve block performance, shorter onset time, and higher SR of surgical anaesthesia compared with NS guidance. US-guided insertion of catheters for continuous peripheral nerve block has increased in popularity, but yet no health economics evaluation has been conducted of US vs NS guidance for continuous peripheral nerve block. In fact, no regular health economic study in strict accordance with the principles of health economic evaluations has ever compared US and NS for peripheral nerve blocks. These principles include the comparison of both costs and consequences of two (or more) alternatives, a systematic framework for identifying, measuring and value resource usage expressed as marginal value (i.e. opportunity cost), and the pursuit of efficiency by identifying interventions that offers the greatest health returns from scarce healthcare resources.6

The purpose of this study is to conduct a cost-effectiveness analysis of US vs NS guidance for continuous peripheral sciatic nerve block in Danish elective patients

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undergoing major foot and ankle surgery. The hypothesis was that US guidance for continuous peripheral nerve block is cost-effective compared with NS guidance.

Methods

Health economic evaluation

The cost-effectiveness analysis follows international guidelines for health economic evaluations conducted alongside clinical trials. A health economic evaluation is a comparative analysis of costs and consequences of two or more alternative health technologies. The purpose of a health economic evaluation is to serve as an input for decision-making. The most common types of health economic evaluations are cost-effectiveness analyses and cost-utility analyses. The viewpoint of the analysis is a hospital sector perspective with the patients admitted during the entire study period.

Patient flow and outcome measurements

The efficacy outcomes were drawn from the randomized controlled trial conducted by Bendtsen and colleagues in 2011. The study was approved by the Central Denmark Region Committee on Biomedical Research Ethics and registered in the Clinical Trials Database (CTD number: NCT00497276). A total of 100 patients undergoing elective major foot or ankle surgery (calcaneal osteotomy, subtalar arthrodesis, total ankle replacement, or open ankle arthrodesis) were included in the study after written informed consent. Inclusion criteria were minimum age 18 yr and ASA classification I–III. Exclusion criteria were neuropathy of the sciatic or femoral nerves, impaired sensory or motor function of the lower extremities, diabetic neuropathy, Charcot–Marie–Tooth disease, local infection in the popliteal fossa, systemic infection, coagulopathy, significant peripheral vascular disease, allergy to local anaesthetics, inability to comprehend the numeric rating scale (NRS), communicative disability, dementia, BMI above 35, and need for bilateral surgery.

The patients were recruited consecutively and prospectively from May 2007 to September 2009 at Aarhus University Hospital, Denmark. After written informed consent and inclusion, the patients were randomly assigned on the day of surgery to either the US group or the NS group using a computer-generated sequence of random numbers and sealed envelopes.

The observations of time used for catheterization and postoperative surveillance and bedside administration of medicine were performed with a stopwatch by independent observers who were not blinded to study group allocation.

All popliteal catheter placements were performed before operation by four staff anaesthetists with the patients in the prone position. The site of needle insertion was the midpoint between the tendons of biceps femoris laterally and semimembranosus and semitendinosus muscles medially 7 cm proximal to the popliteal fossa crease. Group NS: the popliteal catheter (Contiplex catheter 20 G, 400 mm; Braun, Melsungen, Germany) placements were performed with an electrical nerve stimulator (Stimuplex HNS 12; Braun). The stimulation needle (18 G, 55 mm, 15° facet bevel) was inserted at the needle insertion site in the sagittal plane cephalad and 45° angle to the skin until appropriate distal motor response (dorsiflexion or plantarflexion of the foot or toes, or inversion), with a reduction in the current from the initial 1.5 to 0.5 mA or less, at a frequency of 2 Hz, and a stimulation duration of 0.1 ms. If an appropriate motor response was not obtained, the needle was withdrawn to the skin level and reoriented 15° lateral—gauged by the rule of thumb—and reinserted. If the result was still negative, the insertion point was positioned 1 cm lateral to the primary point, and the procedure was repeated. After obtaining an appropriate motor response, 5 ml of saline was injected, the needle was removed, and the catheter was inserted via the sheath.

Group US: the popliteal catheter placements were performed with a Micromaxx or M-Turbo (from November 2008) US unit with a 6–13 MHz linear transducer (HFL38; Sonosite, Bothell, WA, USA) covered by a sterile sleeve. The transducer was placed in the popliteal fossa, and the popliteal neurovascular structures were imaged in short axis. The bifurcation was traced, and the needle (same as the NS group) was advanced out of plane aiming just proximal to the sciatic bifurcation and until contact between the needle tip and the target nerve as judged from movement of the nerve and visualization of the needle tip. Five millilitres of saline were injected to verify the appropriate position of the needle tip with perineural spread of the saline. The needle was withdrawn and redirected as necessary until this endpoint was reached. The needle was removed, and the catheter was inserted via the sheath. In both groups, the catheter was introduced 3 cm beyond the introducer sheath. All catheters were fixed to the skin with a snap-lock (Lockit plus; Smiths Medical ASD, Inc., Keene, NH, USA) and covered by a transparent dressing (IV3000 1-Hand; Smith & Nephew Medical Ltd, Hull, UK) before the local anaesthetic was injected. The standardized dose of 30 ml of ropivacaine 0.75% was injected via the catheter before operation immediately after fixation of the catheter in increments of 5 ml and with intermittent aspirations. By the end of surgery, the surgeon executed a subcutaneous block of the saphenous nerve with 15 ml of bupivacaine 0.5% proximal to the malleolar level from the Achilles tendon to the medial edge of the tibial anterior margin in all patients.

All patients were anaesthetized using propofol and remifentanil. Airway management was done using a laryngeal mask.

Three hours after the initial local anaesthetic bolus, a bolus of bupivacaine 0.25% 15 ml was injected via the popliteal catheter, and an infusion of bupivacaine 0.25% 5–10 ml h⁻¹ was initiated starting at 8 ml h⁻¹. Breakthrough pain was managed with an additional bolus of bupivacaine 0.25% 15 ml (maximum four times per 24 h) and the infusion velocity was increased to 10 ml h⁻¹. If the bolus of bupivacaine did not alleviate the pain effectively after 15 min, i.v. morphine was administered. When the NRS pain score was
The mean costs and effects were calculated for each group in continuous variables and the patient characteristics were compared using the t-test for categorical variables. The mean costs and effects were calculated for each group in the trial. Non-parametric bootstrapping was applied to estimate the standard error and the confidence interval for the mean costs and effects using 1000 samples drawn from the primary sample of data in the Bendtsen and colleagues trial by simple random sampling with replacement. Each repeated sample drawn from the primary sample of data contained the same number of observations as the original sample.

The ICER was calculated to estimate the extra costs of obtaining one extra successful block with US compared with NS.

The non-parametric bias-corrected bootstrapping method was used to test the robustness of the cost-effectiveness result in a multi-way analysis. In total, 4000 extra draws were carried out to estimate the statistical inaccuracy of the estimate of the expected ICER, and used to calculate the probability that US leads to better effects and lower costs. The minimum and maximum proportion of point estimates below any possible threshold value of willingness to pay for better effect was used to estimate the minimum and maximum likelihood that US is cost-effective. All statistical analyses were carried out using Stata version 11 (StataCorp LP, College Station, TX, USA).

## Results

A summary of patient characteristics is reproduced in Table 1.

The target sciatic nerve was successfully located at the popliteal fossa level, and catheter placement was completed in all included patients with US or NS technique as decided by group allocation. All patients received allocated intervention.

### Table 1 Patient characteristic data (n=98). Reproduced from Bendtsen and colleagues. $^2$ Values are mean (SD) except for gender, ASA, and surgical procedures that are presented as number (%) and age that is presented as mean (range). US, ultrasound group; NS, nerve stimulation group

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>US (n=50)</th>
<th>NS (n=48)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>56.5 (19–77)</td>
<td>56.2 (19–74)</td>
<td>0.91</td>
</tr>
<tr>
<td>Gender (male/ female)</td>
<td>32/18 (64/36)</td>
<td>28/20 (58/42)</td>
<td>0.57</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>83.4 (15.7)</td>
<td>81.5 (15.8)</td>
<td>0.56</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>175 (9.4)</td>
<td>174 (7.7)</td>
<td>0.33</td>
</tr>
<tr>
<td>BMI</td>
<td>27.0 (4.0)</td>
<td>26.9 (4.4)</td>
<td>0.95</td>
</tr>
<tr>
<td>ASA (I–III)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>15 (30)</td>
<td>23 (48)</td>
<td>0.06</td>
</tr>
<tr>
<td>II</td>
<td>32 (64)</td>
<td>25 (52)</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>3 (6)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Surgical procedures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcaneal osteotomy</td>
<td>7 (14)</td>
<td>6 (12)</td>
<td>0.61</td>
</tr>
<tr>
<td>Subtalar arthrodesis</td>
<td>5 (10)</td>
<td>8 (17)</td>
<td></td>
</tr>
<tr>
<td>Total ankle replacement</td>
<td>24 (48)</td>
<td>25 (52)</td>
<td></td>
</tr>
<tr>
<td>Ankle arthrodesis</td>
<td>14 (28)</td>
<td>9 (19)</td>
<td></td>
</tr>
</tbody>
</table>
and were included in the analysis except two patients who were excluded after allocation to the NS group because of protocol violation (because both patients were included two times in this study (both of them had surgery twice; only the first inclusion was valid)). Table 2 shows the use of resources measured in relevant units and the applied unit costs. The effects of US vs NS are shown in Table 3. Table 4 shows the mean marginal costs. The mean ICER can be calculated from the data in Tables 3 and 4 as the difference in the mean cost between US and NS divided by the mean difference in SR between US and NS (108.1–115.2)/(0.94–0.79). The confidence intervals overlap; however, the mean difference in the effect is significant ($\chi^2$ test, $P=0.03$).

Table 3 Mean effects (SRs). The SR of the NS technology was $\approx 0.79$ (meaning that 79% of the patients have effective sensory sciatic nerve block in a 48 h period post-surgery) compared with 0.94 with the US technique, that is, a mean difference in the effect of 0.15 ($=0.94–0.79$). The confidence intervals overlap; however, the mean difference in the effect is significant ($\chi^2$ test, $P=0.03$).

### Discussion

This analysis of the cost-effectiveness of US vs NS guidance for continuous peripheral sciatic nerve block after major foot and ankle surgery shows that US is highly cost-effective. The SR was significantly improved with US and it was both better and cheaper in $\approx 84.7\%$ of the cases.

Our study is the first health economic evaluation of US vs NS guidance for continuous peripheral nerve block. There are certain limitations to our study, especially regarding omission of costs for education and training in US technique and a possible impact of nerve location/catheter guidance method—and thereby SR—on the patients total length of hospital stay. Also the multiple possible clinical applications of the US devices are not accounted for (e.g. US-guided vascular access, focused echocardiography, and lung US). We believe that including these aspects would generally increase the ‘value for money’ of investments in US devices, and that our estimate of the cost-effectiveness for US is conservative.

The marginal costs evaluated within the current study include three ‘time’ variables (i.e. physician and nurse time to place the catheter, nurse time to monitor the patient after operation, and nurse time during bedside administration of medicine). In health economic evaluations, time is per definition a cost (i.e. the use of scarce resources) and not the same as expenditures such as salaries. The value of freeing up staff to work at alternative activities should ideally reflect the extra health gain that could be obtained from extra scheduled operations, extra caring for patients, or other activities. The true marginal value of time may indeed be both higher and lower than the gross salaries paid per effective hour of labour, which is the standard way of estimating the opportunity cost of physicians and nurses in health economic evaluation. Although the ‘true’ marginal cost of time is difficult to estimate in empirical analyses, it would be wrong not to include these aspects.

Furthermore, this analysis does not consider cost-effectiveness issues in smaller anaesthesia departments or clinics with continuous peripheral nerve block after ambulatory surgery. The generalizability of health economic evaluation are oftentimes questionable due to different organizational settings, relative prices or costs, availability of healthcare resources, variations in clinical practice, etc. Therefore, studies on cost-effectiveness of US vs NS in different clinical and healthcare systems should be conducted.

Compared with previous studies of the costs of US vs NS, a critical difference is the allowance for depreciation of capital expenditures. By distributing the increased capital costs of US on the total life span of the equipment rather than annual budget expenditures in the first year, the increased capital costs of US are shared out on a larger amount of US procedures. This analysis clearly shows that the US costs are outweighed by savings on personal costs and medicine.
The aim of any health economic evaluation is to identify when we can be confident that one health technology is ‘good value’ compared with another. A single trial may not reflect the true result in the population because of stochastic uncertainty. This study quantifies the stochastic uncertainty in the cost-effectiveness result by performing a non-parametric bootstrap analysis to build an empirical estimate of the sampling distribution of the ICER. This approach has been recommended for statistical analyses in economic evaluations conducted alongside clinical trials. The sampling distribution of the ICER is estimated at the given level of marginal costs, however, and it does not include the uncertainty in the estimation of unit costs or the variation in unit costs between organizational settings and different countries. Further work on cost-effectiveness of US should investigate the full potential for cost savings in other settings, especially in smaller anaesthesia units and include expenses for education and training. In conclusion, US guidance for continuous peripheral nerve block is cost-effective, and daring to assume that our results are fairly generalizable to anaesthesia departments similar to ours, US should be applied as the first-choice procedure of nerve localization and catheter guidance when applying continuous peripheral nerve block for patients admitted in larger anaesthesia units.

Declarations of interest
None declared.

Table 4 Marginal costs. Morphine and bupivacaine include costs of syringes, hypodermics, and infusion tubes. Equipment is the cost per patient for devices: US device with transducer including disposables (sterile covers, gel, disinfectant towels) or NS device. Costs are exclusive of VAT. p.o., postoperative; GBP £, pound sterling; CI, 95% confidence interval

<table>
<thead>
<tr>
<th>Resource</th>
<th>Marginal costs (GBP £) US</th>
<th>CI (US)</th>
<th>NS</th>
<th>CI (NS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurse–patient contact, p.o.</td>
<td>54.1</td>
<td>46.2–62.1</td>
<td>63.9</td>
<td>55.9–71.6</td>
</tr>
<tr>
<td>Catheter insertion time, nurse</td>
<td>4.3</td>
<td>3.8–4.7</td>
<td>4.5</td>
<td>3.9–5.1</td>
</tr>
<tr>
<td>Catheter insertion time, physician</td>
<td>9.0</td>
<td>8.0–9.9</td>
<td>9.5</td>
<td>8.3–10.8</td>
</tr>
<tr>
<td>Equipment</td>
<td>6.5</td>
<td>–</td>
<td>0.4</td>
<td>–</td>
</tr>
<tr>
<td>Morphine 1%</td>
<td>2.7</td>
<td>1.7–3.7</td>
<td>4.1</td>
<td>3.1–5.1</td>
</tr>
<tr>
<td>Bupivacaine 0.25%</td>
<td>31.5</td>
<td>30.0–33.1</td>
<td>32.8</td>
<td>31.3–34.2</td>
</tr>
<tr>
<td>Total</td>
<td>108.1</td>
<td>98.7–117.6</td>
<td>115.2</td>
<td>105.3–125.1</td>
</tr>
</tbody>
</table>

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References