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Clinical Investigation

CLINICAL INVESTIGATION

Blood flow index as an indicator of successful sciatic nerve block: a prospective observational study using laser speckle contrast imaging

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Abstract

Background: Laser speckle contrast imaging allows real-time, non-invasive, quantitative measurements of regional blood flow. The objectives of this prospective observational study were to use laser speckle contrast imaging to evaluate blood flow changes after sciatic nerve block, and to determine whether this novel optical technique can evaluate block success.
Methods: This observational study included 63 adult patients undergoing elective lower limb surgery with sciatic nerve block. Blood flow images and blood flow index (BFI) values of toes were recorded using laser speckle contrast imaging 5 min before nerve block and at 5 min intervals until 30 min after sciatic block. The sensitivity, specificity, and cut-off value of laser speckle contrast imaging for predicting successful sciatic block were determined by receiver operator characteristic (ROC) curve analysis.
Results: The BFI values of toes were significantly increased at each time point after successful sciatic block, compared with the baseline value obtained 5 min before nerve block; in failed sciatic block, there were no significant differences. For successful sciatic block, the highest increase of BFI value was at the big toe. BFI increase of the big toe at 10 min after sciatic block has great potential as an indicator of block success. The area under the ROC curve was 0.954 at a cut-off value of 8.48 perfusion units (PU) with a sensitivity of 89% and a specificity of 100%.
Conclusions: Laser speckle contrast imaging might be an early, objective, quantitative, and reliable indicator of successful sciatic block. BFI increase of the big toe not reaching 8.48 PU within 10 min after sciatic block indicates block failure.
Clinical trial registration: NCT03169517.

Keywords: lasers; nerve block; regional blood flow; ultrasonography

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Editor's key points

- Regional anaesthesia may offer significant benefits over general anaesthesia, although block failure can be problematic.
- Objective measures of regional blockade would have clinical utility, especially where subjective assessment is difficult.
- Laser contract speckle imaging, for measuring regional blood flow, reliably detected failed sciatic nerve block.
- Use of this technology to assess regional blockade quality shows promise but requires further study.

Sciatic nerve block is frequently used in lower limb surgery. Choosing a reliable method to evaluate the quality of sciatic nerve block is essential for good clinical practice. Although the pinprick and cold sensory tests are routinely used to identify the quality of sciatic nerve block, these qualitative tests are subjective and sometimes unreliable, especially in elderly patients with neurodegenerative diseases, children, and those who have neuropsychiatric disorders or a language barrier.

Successful peripheral nerve blocks induce sympathetic blockade, which increases local blood flow by vasodilation.[1,2] Laser Doppler perfusion imaging (LDPI) has been used to evaluate microcirculation after peripheral nerve block.[3–5] LDPI can provide quantitative data on blood flow, but this technique is limited by poor temporal resolution.[6] Pulse oximeter technology was reported to predict the postspinal hypotension[7] and indicate block success for brachial plexus block[8] and sciatic nerve block.[9] Pulse oximeter measures changes in perfusion index, but one probe can only be placed on one digit within the same time period. Laser speckle contrast imaging (LSCI) is an optical imaging technique that allows dynamic and contact-free assessment of blood flow over a large field with high spatial and temporal resolution.[10,11] LSCI has been widely applied in neuroscience, dermatology, and ophthalmology.[12–17] The aim of this prospective observational study was to determine whether LSCI is a reliable indicator of successful sciatic block.

Methods

Ethical approval for this study was obtained from the local ethics committee (number TJ-IRB20170401), and was registered with Clinical Trials (NCT03169517). Written informed consent was provided by all participants. Patients scheduled for elective lower limb surgery with sciatic block between May 2017 and September 2017 at Tongji Hospital in Wuhan, China were eligible for this study. Inclusion criteria were: (1) age 18–75 yr; and (2) ASA physical status 1–2. Exclusion criteria were: (1) peripheral vascular disease; (2) toe injury or deficiency; (3) coloured or infected toenails; (4) use of vasodilator drugs before surgery; (5) administration of preoperative analgesic medications; (6) BMI >35; or (7) contraindication to peripheral nerve block, including patient refusal, allergy to local anaesthetics, peripheral neuropathy, or coagulopathy.

On arrival in the anaesthesia induction room, i.v. access and standard monitoring with electrocardiography, non-invasive BP, and pulse oximetry were established. Blood flow images of the toes in the operated limb were obtained by LSCI, and pinprick sensory tests were assessed 5 min before nerve block (t=0) to provide a baseline value. Measurements were performed with patients resting quietly in the supine position. Room temperature was maintained at 24ºC, and all patients were allowed 20 min upon arrival in the anaesthesia induction room to get accustomed to the surroundings before measurement. Ultrasound guidance was performed using a low-frequency (2–5 MHz) curved array transducer (SonoSite M-Turbo; SonoSite Inc, Bothell, WA, USA) for sciatic block.

Patients were placed in the lateral decubitus position with the side to be operated uppermost and the hip and knee flexed. Ultrasound-guided sciatic nerve block was performed using a subgluteal approach.[18] The hyperechoic sciatic nerve at the subgluteal space was identified between the greater trochanter and ischial tuberosity. After infiltration with lidocaine 1%, an 18-gauge, 10-cm Tuohy needle (SonoPlex Nanoline; Pajunk Inc., Geisingen, Germany) connected to a nerve stimulator (Stimuplex, HNS 12, Braun Medical, Melsungen, Germany) was slowly advanced toward the sciatic nerve with in-plane technique guided by ultrasound. Correct needle position was confirmed when foot plantar flexion was maintained at a current of 0.3–0.5 mA. Subsequently, ropivacaine 0.4% (20 ml) was injected after negative aspiration. After the sciatic block, patients were returned to the supine position.

Blood flow images obtained using LSCI and pinprick sensory scores were recorded at 5 min intervals (t=5, t=10, t=15, t=20, t=25, t=30) over a 30 min period beginning at the completion of local anaesthetics injection. At each time point, blood flow images were obtained before conducting pinprick sensory tests. Pinprick sensory tests were performed with a 22 gauge blunt needle on the skin innervated by the sural nerve (the calf), superficial peroneal nerve (dorsum of the foot), deep peroneal nerve (web space between the first and second toes), and tibial nerve (sole of the foot).[19] Pinprick sensation was compared with the contralateral side with the same stimulus. Pinprick test results were scored quantitatively as 1 (sensation) or 0 (no sensation). Blood flow images and pinprick sensory test results were recorded in each patient independently by two investigators (LSCI: X.W.; pinprick sensory tests: W.M.). Non-invasive BP, HR, and oxygen saturation were also recorded at each time point.

A laser speckle blood flow imaging system[16] (SIM BFI-WF, SIM Opto-Technology Co., Ltd, Wuhan, China) was used to measure blood flow. The equipment consists of a wheeled stage, a laser speckle imaging head, and a connection arm that provides the imaging head with the flexibility to move in horizontal and vertical directions within a certain range. The imaging head contains a laser beam with the wavelength of 785 nm and a 12-bit charge-coupled device (CCD) camera. The system illuminates the target area with a laser beam and acquires the speckle pattern via the CCD camera. A filter was installed in front of the CCD camera to eliminate background light. The exposure time of the CCD camera was 20 ms. The position of the patient's foot was perpendicular to the light. The focal distance of the CCD camera was adjusted to obtain a clear image. The distance from the camera to the target area was 20–25 cm. Thirty images were acquired at an interval of 1 s. In each blood flow image, region of interests (ROIs) were selected and blood flow data were analysed using LSCI software (SIM BFI Software, SIM Opto-Technology Co., Ltd.), which expresses values in perfusion units (PU). The LSCI system and software have been validated in human and animal studies by Professor Li and his team.[16,17,20] By using the same circular-ROI selecting tool in the software, we chose five regions on each foot, defined as circular areas of 1 cm in diameter on the nail