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Superior perioperative analgesia with combined femoral–obturator–sciatic nerve block in comparison with posterior lumbar plexus and sciatic nerve block for ACL reconstructive surgery

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Abstract
Purpose The purpose of this randomized controlled study is to compare and evaluate the intraoperative and post-operative outcome of PLPS nerve block and that of femoral, obturator and sciatic (FOS) nerve block as a method of anaesthesia, in performing ACL reconstruction.
Methods Patients referred for elective arthroscopic ACL reconstruction using hamstring autograft were divided in two groups. The first group received combined femoral–obturator–sciatic nerve block (FOS Group) under dual guidance, whereas the second group received posterior lumbar plexus block under neurostimulation and sciatic nerve block (PLPS Group) under dual guidance.
Results The two groups were comparable in terms of age, sex, BMI and athletic activity. The time needed to perform the nerve blocks was significantly shorter for the FOS group ($p < 0.005$). Similarly, VAS scores during tourniquet inflation and autograft harvesting were significantly higher ($p < 0.005$) in the PLPS group and this is also reflected in the intraoperative fentanyl consumption and conversion to general anaesthesia. Finally, patients in this group also reported higher post-operative VAS scores and consumed more morphine.
Conclusions Peripheral nerve blockade of FOS nerve block under dual guidance for arthroscopic ACL reconstructive surgery is a safe and tempting anaesthetic choice. The success rate of this technique is higher in comparison with PLPS and results in less peri- and post-operative pain with less opioid consumption. This study provides support for the use of peripheral nerve blocks as an exclusive method for ACL reconstructive surgery in an ambulatory setting with almost no complications.
Level of evidence I.

Keywords Anterior cruciate ligament · Obturator nerve block · Posterior lumbar plexus nerve block

Abbreviations and acronyms

ACL	Anterior cruciate ligament
PLPS	Posterior lumbar plexus–sciatic
PLPB	Posterior lumbar plexus block
FOS	Femoral–obturator–sciatic
OBN	Obturator nerve
BMI	Body mass index
VAS	Visual analogue score
PCA	Patient control analgesia
PONV	Post-operative nausea and vomiting
PACU	Post anaesthesia care unit

Introduction

Anterior cruciate ligament (ACL) tears are becoming more and more common among athletes, and it is estimated that 250,000–350,000 ACL reconstructions are performed

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annually in the USA with an increasing rate in the last years [5, 24, 35]. An epidemiology study from New Zeeland estimates an incidence of 36.9 injuries needing surgery per 100,000 person years [11].

Anaesthetic techniques for ACL reconstruction have been evolved in the last years, and the use of peripheral nerve blocks is constantly rising, since duration of hospital stay and financial cost are minimized and physiotherapy is early initiated [13, 19, 23, 28, 31, 33]. The commonest peripheral nerve block technique used for arthroscopic ACL reconstructive surgery is the combination of posterior lumbar plexus block and sciatic (PLPS) nerve block. However, posterior lumbar plexus block (PLPB) is accompanied by complications and a significant rate of failure [14, 30]. Alternatively, the combination of femoral, obturator and sciatic (FOS) nerve block can be used.

It is recognized that the quality of analgesia is higher for knee surgery, when obturator nerve (OBN) block is added [12, 20]. As landmark-based techniques for blocking OBN show limited success, ultrasound guidance has been introduced with encouraging results [3, 9, 12, 27]. An ultrasound method accompanied by nerve stimulation for blocking the FOS nerve, in patients operated for ACL reconstruction, has recently been reported by us [25]. In that preliminary study, it was also described how this block was assessed and was reported that ACL arthroscopic reconstruction is feasible under FOS nerve block where all three nerves are blocked individually with dual guidance (ultrasound and neurostimulation) [25].

The purpose of this randomized controlled trial was to evaluate the efficacy of neurostimulation-guided PLPB with dual (ultrasound and neurostimulation)-guided sciatic nerve block and that of dual (ultrasound and neurostimulation)-guided FOS nerve block as a method of anaesthesia, in performing ACL reconstruction. The null hypothesis was that both methods would provide similar intraoperative and post-operative outcomes regarding efficacy, safety and post-operative pain control.

Materials and methods

The study was conducted in a tertiary care University Hospital, and written informed consent was obtained from all patients before entering the study. All recruited patients received standardized anaesthesia and intraoperative care by the same two specialists. Patients between 18 and 45 years, referred for elective arthroscopic ACL reconstruction using hamstring autograft, plus meniscal surgery, and classified as class I and II according to American Society of Anesthesiologists were eligible for the study. Exclusion criteria were ACL revision surgery, serious bleeding disorders, infection at the sites where the blocks were to be applied, diabetes mellitus or peripheral neuropathy, neurologic deficits to the affected limb, known allergy to the study drugs, body mass index (BMI) >35 kg/m^2, psychiatric disorders and communication difficulties. Patients were randomized into two groups by a computer generator.

The first group received combined femoral–obturator–sciatic nerve block (FOS Group) under dual guidance (ultrasound and neurostimulation), whereas the second group received posterior lumbar plexus block under neurostimulation and sciatic nerve block (PLPS Group) under dual (ultrasound and neurostimulation) guidance. One of the two experienced on regional anaesthesia anaesthesiologist performed the peripheral nerve blocks in a quiet separate place in the recovery area. The anaesthesiologist giving the intraoperative care and the orthopaedic surgeon were blinded as in which group the patient was included.

Block technique

On arrival of the patient in the recovery room, intravenous access was established through an 18G intravenous cannula and the standard monitoring (electrocardiography, non-invasive blood pressure and SpO_2) was initiated. Oxygen, at the rate of 5 l/min through a facial mask, was also delivered. Light sedation with 1–2 mg midazolam and 50–100 μg fentanyl was established in order to make the patient comfortable without loosing verbal responsiveness during the performance of the peripheral nerve blocks. The same set of nerve block needles (Stimuplex; B.Braun, Melsungen, Germany) was used, differing only in length.

For the FOS group, the OBN block was performed under dual guidance, with patients in supine position with the thigh of the affected leg slightly externally rotated. The skin area was sterilized and the ultrasound probe with a linear 5–10 MHz transducer (SonoSite, Bothell, WA, USA) was prepared by enclosing it in a sterile sleeve. A sterile 22-gauge 80-mm insulated block needle connected to a nerve stimulator was also prepared. The inguinal ligament and the adductor longus were palpated. The ultrasound probe was positioned opposite to the angle formed by the inguinal crease and adductor longus, with its short diameter approximately 2.5–3.0 cm in the course of the dichotomous of the angle. It was positioned perpendicular to the skin, and the area was scanned with small changes of the angle. In this position, the pectineus muscle, the adductor longus, adductor brevis and part of adductor magnus muscles are visible, and the anterior division of the OBN may be recognizable between adductor longus and adductor brevis, while the posterior division may be seen below adductor brevis. In such cases, tracing the anterior ramus proximally towards the nerve, in the sonographic triangle formed by pectineus, adductor longus and adductor brevis muscles, the ultrasound probe was tilted cephalically and the OBN

was apparent just as it was bifurcated. If the anterior branch was not clearly traceable, the area was scanned with the probe again tilted cephalically from its original position, seeking for a thick hyperechoic image representing nerve and connective tissue. In this plane, next to pectineus and below adductor longus, usually in a depth of approximately 2.0–2.5 cm, a "spider net" image is visualized. Keeping the probe at the best visualized spot, the skin area of the stimulating needle entry site was anesthetized with 1 ml of 1% lidocaine. The entry site was located 2.5–3.5 cm laterally and perpendicularly to the midpoint of the transducer. Then, the needle was inserted through the skin with an out-of-plane approach towards the triangle, aiming the centre of the "spider net". The correct nerve identification was confirmed by elicitation of muscle contractions using the nerve stimulator. The current was set at 0.5 mA, and the stimulation was done without a progressive decrease in the current. After confirmation of correct needle placement, 10 ml of 0.5% ropivacaine was administered. The success of the block was evaluated 30 min later, by checking only the motor function as we have previously described [25]. The patient was asked to lift his leg upwards and then put it down again. If the OBN was successfully blocked, the patient could not lift the leg directly upwards. Instead it was lifted diagonally outwards (upwards and laterally). Next, the patient put the leg down laterally and could not adduct it to medial line. Consequently, after positive assessment, patients were given femoral and subgluteal sciatic nerve blocks, under dual guidance with 25 and 10 ml ropivacaine 0.5%, respectively, without any adjunct.

For the PLPS group, the PLPB was performed under nerve stimulation only, using the approach described by Chayen [7]. The patient was in the lateral decubitus position with his neck, back and hips flexed. The insertion point was 4 cm lateral from midline along the intercristal line. The foot on the side to be blocked was positioned over the dependent leg so that twitches of quadriceps muscle and patella can be seen easily. A sterile 22-gauge 80-mm insulated block needle connected to a nerve stimulator was prepared. Nerve stimulator was set at 1.0 mA, and once the appropriate movement was induced, the current was progressively decreased at 0.5 mA. Then, 30 ml ropivacaine 0.5% was cautiously administered. Next, the sciatic nerve was blocked under dual guidance with 10 ml ropivacaine 0.5% without any adjunct.

In both groups, sensory and motor blocks were assessed every 5 min, to evaluate the progress of anaesthesia, for half an hour with the exception of OBN block in group FOS which was evaluated only for motor function. All patients received paracetamol 1 g i.v. and parecoxib 40 mg i.v. as part of multimodal analgesia before tourniquet inflation. The patients were awake during surgery and in many instances watching the ACL reconstruction on the screen. If the patient was stressed and asked for further sedation, a further 1–3 mg of midazolam was administered. When a patient complained for pain at any point, 50–100 μg fentanyl was administered, and when this was not enough to control the pain, the anaesthetic technique was deemed as failed and converted to general anaesthesia.

Evaluation methods

Pain, using the visual analogue scale (VAS) during graft harvesting, tourniquet inflation as well as during the whole procedure was documented. In both groups, all patients were given post-operative analgesia with patient control analgesia (PCA) of morphine. The solution contained 0.5 mg/ml morphine, and the PCA pump settings were with no background infusion, only bolus doses of 4 ml (2 mg), with a lockout time of 15 min, and a 4-h safety maximum limit of 30 ml (15 mg). Post-operative data regarding VAS scores, total morphine consumption, nausea, vomiting and urinary retention, were documented for 24 h. Finally, patient satisfaction was also documented.

In FOS group, time from the start of the sonographic examination until local anaesthetic administration for the OBN (phase 1) and the femoral and sciatic nerves (phase 2) were recorded. In the same group, time for the whole anaesthetic procedure, including local anaesthetic administration and block assessment for the three nerves, was also recorded. In both groups, data concerning the need for opioids and general anaesthesia were taken. BMI was calculated as weight in kg divided by the square of height in meters. As described in our preliminary study [25], sensory blocks were assessed by evaluating the presence or loss of cold-warm feeling and of a sharp sensation with pinprick testing for the femoral in the anterior thigh and for the sciatic in the sole of foot (2 for normal sensory perception, 1 for loss of cold-warm feeling and 0 for loss of pinprick sensation). The evaluation of the motor block of the femoral nerve was obtained by the patient's ability to extend the leg affected (5 for normal movement, 4 for unable to raise the leg extended against external resistance, 3 for unable to raise the leg extended against gravity, 2 for unable to extend the leg of the operated limb against gravity, after the hip was passively flexed at 45° by the investigator, 1 for able just to bend knee and 0 for no motion). Sciatic block was evaluated by the motion of the foot and ankle joint (3 for normal movement, 2 for unable to push or flex the foot against external resistance, 1 for unable to push or flex the foot against gravity and 0 for no motion).

The study was registered at the www.clinicaltrials.gov registration site, (registration number NCT01194505), and the IRB was obtained by the Scientific Committee of the University Hospital of Larissa with ID number 5938/24-2-2010.

Statistical analysis

Sample size calculation was conducted considering the rate of block failure higher than 15% when PLPB is applied [14] and lower than 1% in the case of combination of FOS nerve block. Based on these assumptions, sample size calculation (G-Power 3.1.9, University of Dusseldorf, Germany) showed that, for an alpha error of 5%, our study would need 45 patients per group in order to have 80% power with 20% beta error. VAS scores and block grades were treated as continuous variables. Data are presented as mean ± standard deviation for numerical distributions and as percentages for categorical characteristics. Statistical analysis employed Chi-square and Student's *t* test, and a *p* value <0.05 was considered significant.

Results

In a study period of 3 years (2013–2016), approximately 200 patients have been referred to our centre for ACL reconstructive surgery. Patients forming the groups of this study were assigned in the two block specialists of our Anesthesiology Clinic (BM & SM). One hundred and six patients were finally enrolled and divided into two groups consisting of 58 and 48 patients (FOS and PLPS groups, respectively). All patients were operated electively in an ambulatory setting for arthroscopic ACL reconstruction using a hamstring tendon autograft by one surgeon. Demographic data of our study population are presented in Table 1. Comparison of the data showed that the two groups were comparable in terms of age, sex, BMI and athletic activity.

Time needed to perform the nerve blocks was 14.0 ± 5.0 min and 19.1 ± 5.6 min for FOS and PLPS, respectively, and this difference was statistically significant ($p < 0.005$). All 58 patients in FOS group showed zero block grades for both femoral and sciatic nerve sensory functions 30 min after the procedure. In contrast, in the PLPS group only 42 of the 48 patients (87.5%) had no sensory feeling regarding the femoral and sciatic nerve distribution. This difference between the two groups was statistically significant ($p < 0.05$). Evaluation of the motor block for both the femoral and sciatic nerve showed no statistically significant differences between the two groups as presented in Table 2.

VAS scores during tourniquet inflation were equal to 0 in 56 patients in FOS group (96.5%) and in 40 patients in PLPS group (83.3%), and this difference was statistically significant ($p < 0.05$). Furthermore, at this point VAS score as a continuous variable showed significant difference between two groups (0.1 ± 0.7 vs. 0.8 ± 1.8 for FOS and PLPS, respectively; $p < 0.05$). In the protocol, elevation of VAS score resulted to the administration of fentanyl in these patients. Harvesting the hamstring autograft, which included the gracilis tendon, was accompanied also by

Table 1 Patient characteristics [values in mean ± SD or *n* (%)]

	Group FOS	Group PLPS	*p* value
n_{patients}	58	48	
Male sex	51 (87.9%)	40 (83.3%)	n.s.
Age (years)	26.4 ± 8.0	29.1 ± 9.6	n.s.
Weight (kg)	76.7 ± 10.0	77.9 ± 11.3	n.s.
Height (m)	1.7 ± 0.07	1.75 ± 0.06	n.s.
BMI (kg/m^2)	24.5 ± 2.8	25 ± 3.0	n.s.
Athletes	25 (43.1%)	24 (50.0%)	n.s.

Table 2 Pre-operative data (values in mean ± SD)

	Group FOS* ($n = 58$)	Group PLPS** ($n = 48$)	*p* value
Time for performing blocks (min)	14.0 ± 5.0	19.1 ± 5.6	<0.005
Tourniquet time (min)	75.4 ± 16.1	77.9 ± 20.7	n.s.
Sensory block grade *F* and *S* = 0 (pts)	58 (100%)	42 (87.5%)	<0.05
Sensory block grade *F* = 1 (pts)		5 (10.4%)	
Sensory block grade *S* = 1 (pts)		2 (4.1%)	
Motor block grade *F* and *S* = 0 (pts)	53 (91.3%)	38 (79.1%)	n.s.
Motor block grade *F* = 1 (pts)	1 (1.7%)	3 (6.2%)	
Motor block grade *F* = 2 (pts)		2 (4.1%)	
Motor block grade *F* = 3 (pts)		2 (4.1%)	
Motor block grade *F* = 4 (pts)		2 (4.1%)	
Motor block grade *S* = 1 (pts)	5 (8.6%)	1 (2%)	
Motor block grade *S* = 2 (pts)		3 (6.2%)	
Motor block grade *S* = 3 (pts)		1 (2%)	

F femoral, *S* sciatic

* In group FOS the total dose in ml of a solution containing ropivacaine 0.5% was 45 ml

** In group PLPS the total dose in ml of a solution containing ropivacaine 0.5% was 40 ml

elevation in VAS scores in both groups, to 1.07 ± 2.2 for FOS group and to 1.5 ± 2.8 for PLPS group (Table 3). In most of these cases, in both groups, the patients were others than those who were sedatived previously.

Table 3 shows the patients' perioperative use of drugs. One patient, in FOS group, complained for pain during autograft harvesting, and sedation was provided to a degree making the use of laryngeal mask necessary. Eight patients (16.6%) in the PLPS group, on the other hand, had to receive general anaesthesia with the insertion of a laryngeal mask. This difference was statistically significant between the two groups ($p < 0.05$).

The post-operative pain scores were higher for the PLPS group, and this is also reflected in the higher morphine consumption by this group (Table 3). Perioperative shivering and post-operative nausea and vomiting (PONV) showed no statistically significant differences between groups, while no patient complained for urinary retention. All patients in both groups (except those who received general anaesthesia) were very satisfied by their anaesthesia–analgesia and the total management.

Discussion

The most important finding of the present study was that the combination of FOS nerve block provides better analgesia for ACL reconstructive surgery. This study also confirms that ACL reconstruction can be safely performed solely under peripheral nerve blocks. According to our results, the FOS nerve block was more effective, in comparison with the more conservative PLPS approach of nerve block, in terms of post-operative pain control and morphine consumption. In addition, pain and discomfort during tourniquet inflation and graft harvesting was significantly higher in patients received PLPS block. Similarly, conversion to general anaesthesia was significantly higher in patients received PLPS block, since fewer patients in this group had a complete sensory and motor blockade after the nerve block procedure.

ACL reconstruction surgery is being performed increasingly in the ambulatory setting, reaching an almost 40% increase in comparison with inpatient ACL reconstructions [5]. This fact could explain the change also in the anaesthetic technique. According to Buller et al. [5], from 1994 to 2006, a significant increase was recorded concerning the use of regional blocks (0.7–30.8%) in combination with general anaesthesia or not.

The PLPB, also known as psoas compartment block, is a block known since the 1970s [7, 34] and is traditionally performed under neurostimulation [6]. The limitation of its popularity is due to the potential serious complications [4]. The complications of this block are numerous and more serious as it is more than a simple "peripheral nerve block" due to its proximity to the epidural space, the ovarian/testicular vessels, the ureter, the retroperitoneal space and the lower pole of the kidney. Therefore, apart from complications that are expected in every peripheral nerve block, total spinal anaesthesia, epidural spread of the local anaesthetic, renal haematoma or pneumocele may happen with this block [1, 6, 8]. The use of ultrasound guidance could reduce the incidence of the complications mentioned above [10]. However, scanning of the lumbar plexus and directing the needle in real time under ultrasound guidance can be really challenging. Using ultrasound to perform this block has some limitations, and its impact on everyday clinical practice is doubtful [15, 18, 21, 32]. The reason is that the plexus lies deeply between the muscles and the "acoustic

Table 3 Perioperative data (values in mean ± SD)

	Group FOS ($n = 58$)	Group PLPS ($n = 48$)	p value
VAS (t) = 0 (pts)	56 (96.5%)	40 (83.3%)	<0.05
VAS (t)	0.1 ± 0.7	0.8 ± 1.8	<0.05
VAS (g) = 0 (pts)	47 (81%)	38 (79.1%)	n.s.
VAS (g)	1.07 ± 2.2	1.5 ± 2.8	n.s.
Initial dose of dormicum (mg)	1.8 ± 0.8	1.9 ± 0.7	n.s.
Initial dose of fentanyl (mcg)	86.2 ± 34.7	93.7 ± 30.2	n.s.
Fentanyl during procedure (mcg)	35.3 ± 55.4	118.7 ± 115.6	<0.005
Propofol during procedure (mg)	1.7 ± 13.1	144.6 ± 356.5	<0.05
Total dose of morphine (mg)	13.3 ± 7.7	20.9 ± 14.7	<0.005
LMA (pts)	1 (1.7%)	8 (16.6%)	<0.05
Shivering	12 (20.6%)	11 (22.9%)	n.s.
PONV	1 (1.7%)	0 (0%)	n.s.

VAS (t) is for score during tourniquet inflation

VAS (g) is for score during graft harvesting

LMA is for using laryngeal mask during the procedure (conversion to general anaesthesia)

shadow" that is created by the transverse processes makes the visualization of the plexus a real challenge [15, 18]. Karmakar et al. [17] have tried to present a potentially helpful approach in healthy volunteers and in patients [16] with low BMI. We did not have any serious complications in our series directly related to the PLPS block technique, not even urinary retention. There were only two patients that mentioned feeling their other leg heavy (femoral sensory score 1 and femoral motor score 3), about 30 min after the execution of the PLPB, implying a possible epidural spread, but without any hemodynamic implications.

The addition of OBN block to the combination of femoral and sciatic nerve block seems to be the key of success for arthroscopic ACL reconstruction surgery exclusively under peripheral nerve blockade. This has been verified by the study of Sakura et al. [22]. In the past few years, different approaches for ultrasound-guided OBN block have been proposed [2, 12, 26, 27]. In addition, our preliminary study [25] demonstrated that arthroscopic ACL reconstruction can be performed under the combination of FOS nerve block. Our findings can be considered in context with the results from the preliminary study by Helayel et al. [12].

The higher rate of success with the FOS block (confirmed by motor and sensory evaluation) in comparison with PLPS block can be explained by the fact that in the FOS group the local anaesthetic is infused with the use of ultrasound around the femoral and the obturator nerve, while in the LS group it is infused blindly into the plexus. This fact (addition of OBN block) could also explain the less VAS score in the FOS group during tourniquet infusion and autograft harvesting since the OBN is responsible for the sensory innervation of the skin of the medial aspect of the thigh and it is also responsible for the motor innervation of the gracilis. Subsequently, the higher rate of conversion to general anaesthesia in the PLPS group, because of pain and discomfort during surgery, can be attributed to the inferior quality of the OBN block with this technique.

Another interesting point is that total time needed to perform the FOS block was shorter, even though three nerves are blocked compared to the PLPS group that includes two nerve blocks. This can be explained by the fact that femoral and OBN blocks are two superficial nerve blocks performed under dual guidance, in contrast with the PLPB that is a deep block performed only with neurostimulation.

Regarding the post-operative period, the patients in the FOS group had less pain according to VAS and consumed less morphine in the first 24 h post-operatively than the patients in the PLPS group, and this was statistically significant. However, no differences between the two groups were noted regarding adverse reactions like shivering and PONV. All patients from both groups that did not end up receiving general anaesthesia by-passed the post-anaesthesia care unit (PACU) and resumed eating and drinking immediately after the completion of the surgery. These two facts, no delay in the PACU and eating and drinking freely, were proven very important to our young and athletic population of our study and increased their satisfaction.

Tharwat et al. [29], in their study of 48 patients totally, compared the combination of PLPS nerve block with the combination of FOS nerve block for ACL reconstruction. They found that the two combinations are comparable intraoperatively, but the PLPS nerve block offered better post-operative analgesia with less opioid consumption. These findings are not supported by our study, where the combination of FOS nerve block under dual guidance offers higher success rates, and less post-operative pain. This difference between the two studies could be explained by the fact that Tharwat et al. [29] performed the blocks solely under neurostimulation, without any ultrasound guidance.

Limitations of this study are that the patients were young and without comorbidities. It is not known if the success rate of the FOS group will be affected by obesity or senility, as both these factors influence the quality of the image attained by the ultrasound. Also, it is unpredictable how patients with comorbidities, such as diabetes mellitus, will react. Furthermore, we did not have a control group receiving only general anaesthesia, to compare our results with the traditional anaesthetic management of patients undergoing ACL reconstructive surgery.

In total, this study demonstrates that FOS nerve block under dual guidance for ACL reconstructive surgery is an alternative option. Using this anaesthetic technique, ACL reconstruction can be performed as one-day case surgery, saving time and money. In busy operation theatres, patients receive high quality anaesthesia care, avoiding the catastrophic complications of the PLPB.

Conclusions

This study demonstrates that peripheral nerve blockade of FOS nerve block under dual guidance for arthroscopic ACL reconstructive surgery is a safe and tempting anaesthetic choice. The success rate of this technique is higher in comparison with PLPS nerve block and resulted in less peri- and post-operative pain with less opioid consumption.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest to report.

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Ethical approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included to the study.

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