

Time Sequence of Sensory Changes after Upper Extremity Block

Swelling Sensation Is an Early and Accurate Predictor of Success

Xavier Paqueron, M.D.,* Marc E. Gentili, M.D.,† Jean Claude Willer, M.D., Ph.D.,‡ Pierre Coriat, M.D.,§ Bruno Riou, M.D., Ph.D.||

Background: Sensory assessment to estimate spread and effectiveness of a peripheral nerve block is difficult because no clinical test is specific for small sensory fibers. Occurrence of a swelling illusion (SI) during a peripheral nerve block corresponds to the impairment of small sensory fibers. The authors investigated the usefulness of SI in predicting successful peripheral nerve block by assessing the temporospatial correlation between progression of sensory impairment in cutaneous distributions anesthetized and localization of SI during peripheral nerve block installation.

Methods: Interscalene, infraracoid, or sciatic nerve blocks were performed using a nerve stimulator and 1.5% mepivacaine in 53 patients, with a total of 201 nerves to be anesthetized. Pinprick, cold, warm, touch, and proprioception were assessed every 3 min, while patients were asked to describe their perception of size and shape of their anesthetized limb and localization of these illusions. Data are presented as mean \pm SD and percentage (95% confidence interval).

Results: Failure occurred in 12 cutaneous distributions out of a total of 201 theoretically blocked nerves. SI appeared earlier than warmth impairment (4.3 ± 2.7 vs. 6.2 ± 2.0 min; $P < 0.05$), always corresponding to successfully anesthetized cutaneous distributions, with the exception of 1 patient, who developed SI in 2 cutaneous distributions while sensory testing indicated failure in 1 distribution. SI successfully predicted the blockade of a cutaneous distribution with a sensitivity of 1.00 (0.98–1.00), a specificity of 0.92 (0.65–0.99), and an accuracy of 0.99 (0.97–1.00).

Conclusions: Swelling illusion may provide an early assessment of the success of a peripheral nerve block in unsedated patients.

SENSORY assessment of regional anesthesia is a common practice in clinical anesthesia to estimate both spread and effectiveness of the sensory block after a peripheral nerve block (PNB) before surgery. Anesthesiologists assume usually that the lack of sensation to simple stimuli such as touch, pinprick, or cold applied on the skin of

patients predicts the absence of pain during surgery. Unfortunately, these common simple stimuli do not represent a totally accurate or reliable assessment method of the nociceptive block during surgery because they cannot predict complete blockade of the nociceptive small-diameter C fibers and A δ fibers (see the recent review by Curatolo *et al.*¹). Indeed, these simple stimuli used in clinical anesthesia are poor indicators of the blockade of the nociceptive fibers.^{2–4} Cold and pinprick activate A δ fibers but not C fibers, which are activated by warmth (42° – 46° C). Therefore, the ability of these tests to predict the effectiveness of a PNB is limited because the accurate clinical assessment of the blockade of small-diameter sensory C and A δ fibers remains uncertain.

However, animal as well as human studies strongly support the hypothesis that small-diameter sensory C and A δ fibers are major determinants of the perception of one's body image and may provide a source of tonic modulation of the cortical representation of the limb.^{5–8} It is well known that dental anesthesia induces a sensation of swelling of the lips and of other parts of the face, and in a previous study, we showed that perceptual distortions of body size and shape induced by regional anesthesia are probably related to the functional impairment of A δ - and C-fiber activity.⁸ These perceptual distortions of body size and shape occur early during the installation of a regional anesthesia and are mainly described as sensations of enlargement (or swelling) of the anesthetized limb. Furthermore, we observed that the swelling illusion is confined to the anesthetized and follows a somatotopic distribution. Therefore, one might view a direct functional approach to C- and A δ fibers activity or level of blockade by assessing these perceptual distortions of body size and shape (these perceptual distortions of body size and shape are referred as *swelling illusion* throughout this article) during the course of installation of a sensory block after a PNB. Therefore, we hypothesized that the perception of this swelling illusion during the installation course of a PNB could be an early and accurate predictor of both spread and effectiveness of the sensory block.

Materials and Methods

After this study was approved by the local institutional review board (Comité Consultatif pour la Protection des Personnes dans la Recherche Biomédicale, Pitié-Sal-

* Assistant Professor, § Professor of Anesthesiology, Chairman, Department of Anesthesiology, ‡ Professor of Neurology, Chairman, Department of Clinical Neurophysiology, || Professor of Anesthesiology, Chairman, Department of Emergency Medicine and Surgery, Centre Hospitalo-Universitaire Pitié-Salpêtrière, † Staff Anesthesiologist, Department of Anesthesiology, Centre Médico-chirurgical Saint Vincent.

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Address correspondence to Dr. Paqueron: Département d'Anesthésie-Réanimation, Centre Hospitalier Universitaire Pitié-Salpêtrière, 47 Boulevard de l'Hôpital, 75651 Paris Cedex 13, France. Address electronic mail to: xavier.paqueron@psl.ap-hop-paris.fr. Individual article reprints may be purchased through the Journal Web site, www.anesthesiology.org.

pêtrière, Paris, France), patients undergoing orthopedic surgery during regional anesthesia and who gave their informed consent according to the principles of the Helsinki convention were enrolled. Exclusion criteria were the existence of neurologic disease, diabetes mellitus, cutaneous infection at the site of needle puncture, or a level of pain above 30 on a visual analog scale ranging from 0 (no pain) to 100 (maximum pain imaginable). No patient received any sedative or opioid drug before or during the study period.

Peripheral Nerve Blocks

Standard monitoring was applied to all patients undergoing interscalene (ISB), infraclavicular (ICB), or sciatic (SNB) nerve blocks. ISBs were performed using Winnie's landmarks,⁹ and ICBs were performed with the infraracoid approach described by Jandard *et al.*¹⁰ All SNBs were performed using the parasacral approach described by Mansour.¹¹ After cutaneous landmarks had been drawn on the skin and after skin disinfection, a 22-gauge 25-, 50-, or 100-mm insulated needle (Stimuplex B; B. Braun, Boulogne-Billancourt, France) connected to a peripheral nerve stimulator (Stimuplex[®] HNS 11; B. Braun, Melsungen, Germany) was used to identify nerves according to their specific motor-evoked response as follows: for ISB: flexion or extension of the elbow or contraction of the deltoid muscle; for ICB: median nerve (flexion and pronation of the wrist, flexion of the second and third fingers)-, ulnar nerve (fourth and fifth fingers flexion and thumb adduction)-, or radial nerve (wrist and finger extension)-evoked motor response; and for SNB: tibial nerve (plantar flexion of the foot) or peroneal nerve (dorsal flexion or eversion of the foot) evoked-motor response. Specific motor responses were sought with the nerve stimulator set at 1-Hz frequency, 100 μ s, and a current of 1.5 mA, then progressively reduced to 0.5 mA or less before injection of local anesthetic solution (1.5% mepivacaine). All blocks were performed using a single-injection technique to avoid any time lag in the onset of the anesthetic block that might be the consequence of performing the blocks with a multiple stimulation and injection technique. The volume of mepivacaine administered was 20 ml in SNBs, 30 ml in ISBs, and 30–40 ml in ICBs.

Assessment of Sensory and Motor Functions

Immediately after the end of block placement (*i.e.*, withdrawal of the needle), the anesthetized limb was hidden from the patient's sight with a drape. The sensations elicited by pinprick, cold (compress soaked with alcohol at 16°C), heat (glass test tube containing water at 44°C), and gentle rubbing stimuli; the accuracy of position sense (by moving a limb segment from its original position and by asking the patient to show its new position by using the opposite joint); and the strength of voluntary movement were assessed immediately after

the end of block placement and then every 3 min for 30 min in the main cutaneous distributions of the brachial and sacral plexus. Sensory and motor functions were assessed on a three-point scale, with 2 corresponding to a normal sensation or movement, 1 corresponding to a blunted sensation or moderately impaired movement, and 0 corresponding to an absence of sensation or movement, as previously described.⁸

Assessment of Perceptual Distortions of Body Shape

Just after the end of block placement, the patients were told that they might experience various alterations in the perception of size, shape, and position of their anesthetized limb. Then, they were encouraged to report their sensations every 3 min. The investigator systematically asked the patient to focus on his or her perception of the shape and position of the specific anesthetized area (the term *phantom limb syndrome* was used solely to define the occurrence of a postural illusion). The onset time of the swelling illusion was recorded. The patient's subjective description was fully transcribed as follows: The narrative description of the perceptual distortions of shape and position involving fingers, hand, wrist, forearm, and arm described by the patient were drawn by the investigator on a schematic body template to best represent his or her sensations. To avoid any misunderstanding from the investigator, patients also had to validate the drawing. Meanwhile, the classic sensory testing was performed. Furthermore, at each point of measure, the investigator specified whether the spread of the swelling illusion corresponded to the anesthetized area as defined by the classic sensory testing. In case of incomplete sensory block in one or more cutaneous distributions, the investigator had to specify at each time of measure whether the swelling was present or absent in these distributions. Consequently, at the time of data analysis, it was possible to compare the area actually anesthetized using the classic sensory testing (spread and intensity of the block) and the diffusion of the subjective perception of swelling (onset of the sensation and spread drawn on the template).

Correlation between the Swelling Sensation and the Actual Anesthetized Cutaneous Distributions

The analysis of the swelling sensation allows theoretically a global assessment of all the cutaneous distributions that are actually blocked during a PNB. Because the four major nerves (*i.e.*, median, ulnar, radial, and musculocutaneous nerves) of the brachial plexus as well as the two major nerves of the sacral plexus (*i.e.*, tibial and peroneal nerves) have their cutaneous distributions participating in the innervation of the hand and foot, we may gain information about these nerves by asking patients to describe their hand and fingers or foot and toes. We defined, at first, a successful PNB as a diffusion of a

complete sensory block (*i.e.*, all sensations were abolished and scored 0) to all the possible cutaneous distributions that should be blocked if all the peripheral nerves were efficiently anesthetized.¹² According to this definition, the failure of a PNB is a rare event, observed at a frequency of approximately 5% in the case of multiple nerve stimulation and at a frequency of 10–15% after a single-injection technique.^{13–15} Second, after a PNB, the anesthetized limb is not always perceived as uniformly swollen, the sensation of swelling being usually more vivid in the distal part of the limb (foot or hand). Therefore, we studied only the cutaneous distributions involved in the innervation of the forearm, wrist, and hand after upper limb PNB, and those involved in the cutaneous innervation of the leg, ankle, and foot after lower limb PNB.

Consequently, in the case of upper limb PNB, the presence of sensory block was assessed in the cutaneous distributions of the brachial plexus responsible for the innervation of the distal part of the upper limb (*i.e.*, wrist, hand, and fingers) corresponding to the musculocutaneous, median, radial, and ulnar nerves, and we defined a successful brachial plexus PNB as a block in which a complete sensory block was present in all four of these cutaneous distributions. A block that did not anesthetize these four nerves was considered incomplete, and the number of cutaneous distributions actually blocked was recorded. An exception was made for ISB; because the ulnar nerve is inconsistently anesthetized with this approach, we decided that only three cutaneous distributions should be systematically anesthetized at the distal part of the upper limb: median, radial, and musculocutaneous. Similarly, in the case of SNB, the presence of a sensory block was measured in the two major cutaneous distributions of the sacral plexus (*i.e.*, tibial, deep, and superficial peroneal were analyzed as one entity), and we defined a successful SNB as a block in which a sensory block was present in both cutaneous distributions. A block that did not anesthetize these two nerves was considered incomplete, and the number of cutaneous distributions actually blocked was recorded.

Statistical Analysis

Data were expressed as mean \pm SD and percentages (95% confidence interval [CI]). Comparison of means was performed using analysis of variance and the Newman-Keuls test. For the assessment of the swelling sensation to be a predictor of the block, we considered all main nerves blocked as a unit of observation, and not the patient, and we calculated its sensitivity, specificity, negative and positive predictive values, and accuracy. *Sensitivity* is the ratio of the number of patients presenting both a swelling illusion and a sensory impairment over the total number of patients presenting a swelling illusion. *Specificity* is the ratio of the number of patients

Table 1. Main Characteristics of the Patients (n = 53)

Variable	Value
Age, yr	49 \pm 16
Weight, kg	71 \pm 15
Height, cm	169 \pm 9
Male/female	32/21
ASA physical status	
I	23
II	29
III	0
IV	1
Types of peripheral nerve blocks	
Interscalene	3
Infraclavicular	46
Sciatic	4

Values are presented as mean \pm SD.

ASA = American Society of Anesthesiologists.

presenting neither a swelling illusion nor sensory impairment over the total number of patients not presenting a swelling illusion. *Positive predictive value* is the ratio of the number of patients presenting both a swelling illusion and a sensory impairment over the total number of patients with sensory impairment. *Negative positive value* is the ratio of the number of patients presenting neither a swelling illusion nor a sensory impairment over the total number of patients without sensory impairment. *Accuracy* is the sum of the number of patients presenting both a swelling illusion and a sensory impairment and the number of patients presenting neither a swelling illusion nor sensory impairment, divided by the total number of patients.

The 95% CIs of these values were determined. Assuming a *P* value of 0.05 and an accuracy greater than 0.98, we calculated that at least 190 nerves should be studied to obtain a lower limit of the CI of the accuracy greater than 0.96 (nQuery Advisor 3.0; Statistical Solutions Ltd., Cork, Ireland) All *P* values were two sided, and a *P* value of less than 0.05 was considered significant. Analyses were performed using NCSS 6.0 software (Statistical Solutions Ltd).

Results

Fifty-three consecutive patients, whose characteristics are reported in table 1, scheduled to undergo upper (n = 49) or lower extremity (n = 4) surgery during PNB were enrolled. Forty six ICBs, 3 ISBs, and 4 SNBs were performed in these 53 patients, corresponding to a total number of 201 nerves that should have theoretically been blocked if all blocks had been fully successful.

Assessment of Sensory Functions and Success Rate of Block

Sensations to cold and pinprick, then warm were altered first while touch and eventually proprioception became impaired later. Similarly, abolition of these sen-

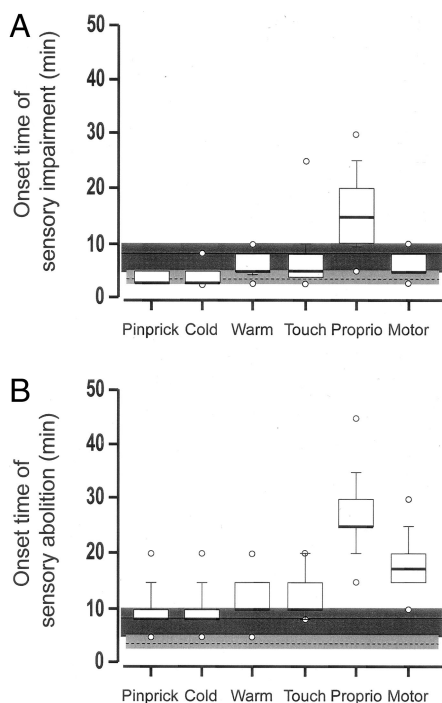


Fig. 1. Time to impairment (A) and to abolition (B) of the sensations elicited by pinprick, cold, heat, touch, proprioception (Proprio), and motricity (Motor). Times to swelling onset (dashed line) and fixed swelling (continuous line) are displayed to provide on the same graph meaningful informations regarding both perceptual distortion of body size and shape (swelling illusion), and alterations, then abolition of classic sensations. The dashed line and the gray area correspond to the median delay to swelling onset and its 25th and 75th percentiles, respectively. The continuous line and the dark gray area correspond to the median delay to fixed swelling and its 25th and 75th percentiles, respectively. Note that when the swelling occurred, the only perceptions altered were pinprick, cold, and heat. Data are presented as median (bold lines) and 25th and 75th percentiles (vertical extension of bars) and extreme values (open circle).

sations followed the same order. The time course of the impairment of abolition of the different sensory modalities is described in figure 1. In all cases of ISB, the cutaneous distribution corresponding to the ulnar nerve remained unanesthetized. In ICBs, complete anesthesia with a spread of anesthesia to the four major nerves of the brachial plexus was observed in 38 of 45 patients. In the remaining patients with incomplete ICB, one and two cutaneous distributions remained unanesthetized in six and one patients, respectively, and among them, three received a complementary block at the elbow. In one patient, a complete ICB failure was observed at 30 min, justifying complementary ulnar and median blocks at the elbow. In all cases of SNB, a complete block was observed. Then, failure involved 12 nerves of a total of 201 nerves that should have been blocked during the study if all blocks had been completely successful among the 53 patients. When considered by nerve, success and failure rates were therefore 94% (95% CI, 90–97%) and 6% (95% CI, 3–10%), respectively. However, when con-

sidered by patient, success and failure rates were 85% (95% CI, 71–92%) and 15% (95% CI, 8–29%), respectively. Finally, in all patients and after complementary block, surgery was performed only during PNB, with none of the patients requiring intraoperative opiates or general anesthesia.

Occurrence and Spread of the Swelling Illusion

The illusion of swelling of the deafferented limb occurred in all but one patient with complete ICB failure (52 of 53 [98%]). As we had previously shown, such sensations were rarely reported at first and were usually acknowledged by the patients only after they had been asked to focus their attention on the perception of the shape of their limb.⁸ The patients could not ignore this perception any longer after they had acknowledged it for the first time, and subsequently providing details about its characteristics clearly did not require an important effort of introspection. We observed that the illusion of swelling initially occurred usually in the cutaneous distribution of the nerve corresponding to the nerve stimulated during the block placement and then quickly spread within minutes to the remaining cutaneous distributions of the anesthetized limb. The swelling illusion occurred before, at the same time as, and after any sensory impairment in 9 (17%), 41 (79%), and 2 patients (4%), respectively. The times to onset of swelling and the end of spread of the illusion of swelling (fixed swelling) were 4.3 ± 2.7 and 8.4 ± 4.7 min, respectively. In all of the patients in the current study, the illusion of swelling appeared more vivid in the distal part of the anesthetized limb.

The relation between the onset of impairment of the different sensory modalities and the illusion of swelling is shown in figure 1. The onset of swelling occurred significantly earlier (approximately 2 min) than impairment of the sensation of warmth ($P < 0.05$ vs. swelling onset). Furthermore, when the illusion of swelling became fixed, sensations to cold, pinprick, and warmth were not abolished ($P < 0.05$, abolition of cold, pinprick, and warmth vs. fixed swelling).

In the three patients who received an ISB in whom the ulnar nerve remained unanesthetized, the illusion of swelling was felt in the wrist, hand, and fingers but spared the medial aspect of the wrist and hand and the fifth finger. Similarly, in the four patients who received an SNB, the illusion of swelling was felt in the entire foot, toes, and lateral aspect of the leg but spared the medial aspect of the leg, which is innervated by the saphenous nerve. With ICB, the illusion of swelling always corresponded to the cutaneous distributions successfully anesthetized, except in one patient with partial failure of the ICB. In this patient, in whom ICB was incomplete with the cutaneous distribution corresponding to the median nerve remaining unanesthetized and requiring a complementary block at 30 min, only a weak illusion of

Table 2. Efficiency of the Swelling Illusion to Predict the Result of the Block (n = 201 Nerves)

Variable	Value (95% Confidence Interval)
Sensitivity	1.00 (0.98–1.00)
Specificity	0.92 (0.65–0.99)
Positive predictive value	0.99 (0.97–1.00)
Negative predictive value	1.00 (0.74–1.00)
Accuracy	0.99 (0.97–1.00)

swelling developed in only two cutaneous distributions (ulnar and radial cutaneous distributions), whereas sensory testing indicated failure in only one distribution (*i.e.*, median nerve).

Prediction of the Block by Swelling Sensation

As shown in table 2, the swelling illusion accurately predicted block. Occurrence of a swelling illusion without a complete nerve block occurred in only one nerve. Conversely, no swelling illusion was reported in an unanesthetized cutaneous distribution of a nerve.

Discussion

In the current study, we observed that the swelling illusion during the onset of a PNB is an early and accurate predictor of the block success.

It has recently been demonstrated in humans that the occurrence of a perceptual distortion of body size and shape (referred to as the swelling illusion in the current study) may denote hypofunction of small-diameter C and A δ sensory fibers.^{7,8} These observations in humans are supported by results in animal studies: First, as demonstrated in animal studies, a single digit deafferentation (amputation or local anesthesia) induces immediate cortical reorganization within the somatosensory cortex. Second, animal studies have shown that acute removal of the afferent inputs from one digit induces an immediate expansion of the receptive fields of cortical cells, which represent skin areas adjacent to the site from which the input was removed.^{5,16} However, the fact that the “enlargement” sensation occurs when an entire limb is deafferented suggests that remapping within the somatosensory cortex may actually not be the cause of this illusion. Thus, perceptual alterations of body shape may be accounted for by disinhibition of background activity within the deafferented cortex. In fact, neuronal recordings in the somatosensory cortex of rats and raccoons have shown increased levels of spontaneous activity after sciatic nerve section¹⁷ or single digit amputation.¹⁸ Third, it was also demonstrated in upper limb amputees that an axillary brachial plexus nerve block could acutely reverse cortical reorganization.^{19,20} This relation between small sensory fiber dysfunction and body shape alteration was found in our previous study, regardless of the site and type of regional anesthesia and the sequence

of sensory impairment. Interestingly, animal studies suggest that peripheral C fibers provide a somatotopically specific source of tonic inhibition to the primary sensory cortex.⁶ Accordingly, the suppression of such inhibitory influence could contribute to the illusion of swelling reported by patients during the course of deafferentation. Taken together, these observations underline the modulatory role of thin C fibers on the perception of shape and size of body parts.

The main clinical interest of the illusion of swelling lies in that it provides probably direct and functional information on the function of small-diameter C and A δ sensory fibers. This may be a highly reliable test of small sensory fibers because results from both animal studies and clinical trials have demonstrated that only small sensory fibers can modulate the perception of our own body size and shape (see above). Moreover, the occurrence of this illusion of swelling is extremely common during the installation of a PNB. In accord with our two previous studies in which such an illusion of swelling occurred in all (36 of 36)⁸ and 96% (50 of 52)²¹ of the patients, the current study found that the illusion of swelling occurred in 98% (52 of 53) of the patients. In their earlier study, Melzack and Bromage previously reported a high incidence of the illusion of swelling because they “reported a sensation of swelling of the fingers in most (9 out of 12) of the patients who were questioned specifically about this matter.”²² However, until now, such sensations were rarely reported because they are usually acknowledged by the patients only after they have been asked to focus their attention on the perception of the shape of their limb. This might explain why Klein *et al.*²³ found a lower incidence of perceptual distortion of body size and shape after upper and lower extremity blocks. In this study, the patients described their anesthetized upper extremity as full or fat, shorter, and thinner in 20%, 18%, and 7% of cases, respectively.²³ In fact, these authors distributed a questionnaire that was filled in by the patients only after being admitted to the recovery room and after receiving intravenous midazolam and fentanyl, but they did not specifically direct the attention of their patients to the size of their anesthetized limb.

The swelling illusion always preserves the somatotopy between the anesthetized nerves and their cutaneous distributions. This is coherent with the physiology of sensory transmission because somatotopy is preserved throughout the nervous system, from the cutaneous nerve endings through the spinal cord, thalamus, and somatosensory cortex.^{6,16,20,24–30} In the current study, as well as in a previous one,⁸ we observed that the swelling illusion always spared cutaneous distributions corresponding to unanesthetized areas, as illustrated by the lack of swelling on the C8 dermatomes after an ISB or by the fact that the medial aspect of the leg always remained normally described after a SNB.⁸ Another im-

portant finding of the current study is that the swelling illusion occurs early (4.4 ± 2.7 min) during the course of installation of a PNB, approximately 2 min earlier than the alteration of the warmth sensation. Furthermore, the swelling illusion takes a shorter time to spread and become fixed (8.4 ± 4.7 min) as compared with classic sensory testing such as pinprick, cold, and warmth, which become abolished 3–4 min afterward.

According to our results, the absence of the swelling illusion predicts with a specificity of 92% and a negative predictive value of 100% the failure of the spread of the PNB to a cutaneous distribution. Thus, the use of such a simple test would be interesting in the clinical assessment of the spread of a PNB and in determining the need for a complementary block, but it should be recognized that the power of this study regarding the assessment of failure is low (see next paragraph). However, the main result of the current study is to show that the occurrence of the swelling illusion represents an early and accurate predictor of the efficiency of a PNB. It provides an earlier functional assessment of the small sensory fibers than the classic sensory testing using cold, pinprick, and warmth, and it also predicts with high accuracy (99%) the spread of the PNB to the cutaneous distributions actually blocked. Finally, the analysis of the swelling illusion represents an easy test to assess efficiently the future success of a PNB, in terms of both sensory fiber blockade and spread of the block.

Some remarks should be included to assess the limitations of our study. First, the main limitation was that our study was at least partially based on the patient's subjective reporting. Because the sensations investigated usually were not reported by the patients spontaneously but rather when they were asked to direct their attention to their anesthetized limb, suggestions from the investigator may have influenced the patients' answers. This limitation cannot be overcome in studies on the awareness of one's own body. Therefore, the inquisitive character of our study was necessary to draw the patient's perceptual experience of his or her body out of its "natural obscurity."³¹ Second, only unsedated patients were studied to avoid the bias related to the administration of sedative drugs. Opiates might impair the perception and description of sensations, and benzodiazepines might induce not only sedation but also amnesia. However, it is common practice to administer sedatives to patients undergoing PNBs, and light sedation probably does not greatly impair the perception of the swelling illusion. However, the current study did not address the influence of light sedation on the perception of perceptual distortion of body shape. Therefore, the applicability of our findings in sedated patients remains uncertain. Third, the qualitative nature of our multimodal sensory assessment is another limitation because the time course of sensory block is less accurately precisely described by such a method than by threshold determinations.^{1,32}

However, the simplicity and rapidity of the qualitative assessment allowed concomitant measurement of both sensory impairment and distortions of body size and shape at close intervals, which was the main objective of this study. Last, the efficiency of a swelling sensation should be better assessed by considering only failures of nerve block. Because we studied only 12 failures, the power of our study is too low. Nevertheless, because administering an additional block may not be without clinical consequences, we considered that the accuracy (including both false positives and false negatives) was more appropriate and obtained sufficient power for this variable.

As it had been suggested in the prime opus of Melzack and Bromage,²² there is a strong relation between modifications of one's body perception of an anesthetized limb and the effectiveness of neural blockade. We provide new evidence that sensory function can be accurately assessed by examining the occurrence and spread of the perceptual distortion of body size and shape after a PNB. This swelling illusion appears early during the time course of the installation of the neural blockade. Furthermore, such an illusion has never been observed in unanesthetized cutaneous distributions. Therefore, searching this illusion and its localization could represent an early predictor of PNB spread failure, when swelling is not present after 5–8 min in one or more cutaneous distributions after a PNB. Further research is necessary, and specifically, a prospective, double-blind, randomized study must be conducted to compare the effectiveness of the illusion of swelling *versus* conventional sensory testing in assessing the success rate and decision to administer an additional nerve block in the case of incomplete PNB.

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