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Continuous Peripheral Nerve Blocks in Hospital Wards after Orthopedic Surgery

A Multicenter Prospective Analysis of the Quality of Postoperative Analgesia and Complications in 1,416 Patients

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Background: **Continuous peripheral nerve block (CPNB) is the technique of choice for postoperative analgesia after painful orthopedic surgery. However, the incidence of neurologic and infectious adverse events in the postoperative period are not well established. This issue was the aim of the study.**

Methods: **Patients scheduled to undergo orthopedic surgery performed with a CPNB were prospectively included during 1 yr in a multicenter study. Efficacy of postoperative analgesia, bacteriologic cultures of the catheter, and acute neurologic and infectious adverse events were evaluated after surgery in 1,416 patients at arrival in the postanesthesia care unit, at hour 1, and every 24 h up to day 5. Risk factors for adverse events were determined using logistic regression.**

Results: **The median duration of CPNB was 56 h. Both general anesthesia and CPNB were performed in 73.6% of the patients. Postoperative analgesia was effective in 96.3%, but an increase in pain scores was noted at hour 24 ($P = 0.01$). Hypoesthesia or numbness occurred in 3% and 2.2%, respectively, and paresthesia occurred in 1.5%. Three neural lesions (0.21%) were noted after continuous femoral nerve block. Two of these patients were anesthetized during block procedure. Nerve damage completely resolved 36 h to 10 weeks later. Cultures from 28.7% of the catheters were positive. Three percent of patients had local inflammatory signs. The bacterial species most frequently found were coagulase-negative staphylococcus (61%) and gram-negative bacillus (21.6%). A *Staphylococcus aureus* psoas abscess (0.07%) was reported in one diabetic woman. Independent risk factors for paresthesia/dysesthesia were postoperative monitoring in intensive care, age less than 40 yr, and use of bupivacaine. Risk factors for local inflammation/infection were postoperative monitoring in intensive care, catheter duration greater than 48 h, male sex, and absence of antibiotic prophylaxis.**

Conclusion: **CPNB is an effective technique for postoperative analgesia. Minor incidents and bacterial colonization of catheters are frequent, with no adverse clinical consequences in the large majority of cases. Major neurologic and infectious adverse events are rare.**

This article is accompanied by an Editorial View. Please see: Klein SM: Continuous peripheral nerve blocks: Fewer excuses. ANESTHESIOLOGY 2005; 103:921–3.

THE use of peripheral nerve blocks is recommended after orthopedic surgery.[1] Continuous peripheral nerve blocks (CPNBs) have been shown to promote better postoperative analgesia, increase patient satisfaction, and have a positive influence on the surgical outcome and patient rehabilitation compared with intravenous opioids for both the upper[2,3] and lower extremities.[4,5] CPNB offer the advantage of prolonged analgesia with lesser side effects than intravenous morphine, patient-controlled analgesia, or epidural analgesia.[2–5] There is increasing interest in CPNB because of potential benefits and concerns about interactions of anticoagulants and central neuraxial techniques. Some studies involving CPNB included relatively few patients. Moreover, these studies being comparative *versus* control groups, the number of actual CPNB patients was lower than the number recruited.[2–7] The studies with the greatest number of patients were retrospective, necessitating long periods of inclusion,[8,9] or focused on one type of surgery or one CPNB technique[10–13] or only on pain relief.[14,15] Because complications related to CPNB are rare, their incidence can only be roughly estimated,[8,10–14] and the complications of more recently introduced techniques could not be ascertained in the previous retrospective series. Furthermore, risk factors for adverse events during CPNB have never been studied. In the current multicenter trial, we prospectively studied 1,416 patients scheduled to undergo orthopedic surgery and CPNB to determine the quality of postoperative analgesia and the incidence of neurologic and infectious adverse events and complications.

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Materials and Methods

After we received institutional review board approval (Montpellier, France, principal investigator's review board), approval of all other institutions, and written consent of each patient, 1,422 consecutive adult patients scheduled to undergo orthopedic surgery were recruited for the study in eight university hospitals between January 1, 2000, and December, 31 2000.

Patients were aged 18 yr or older and admitted for orthopedic surgery for which the postoperative management program included a CPNB. Patients who did not cooperate and those who had psychological disorders or linguistic difficulties that might interfere with pain assessment were excluded. Medical exclusion criteria were severe bronchopulmonary disease, blood clotting impairment, history of recent local or systemic infection, known allergy to the trial drugs, any previous damage to the nerve or plexus, neuropathy, and cardiac conduction problems (second- or third-degree atrioventricular block). In addition, patients having participated less than 1 month previously in a therapeutic trial and those who were already participating in another study were not included in the current study. The anesthesiologist participating in the study in each hospital decided the type of block depending on the surgical procedure.

The following procedures were standardized:

- A conventional aseptic procedure was used to insert the CPNB catheter: The anesthesiologist wore a mask, cap, sterile gown, and gloves. The puncture site was prepared with a 10% povidone-iodine solution, and surrounding areas were covered with sterile drapes.
- The continuous perineural blocks were positioned using nerve stimulators except when fascia iliaca compartment placement was involved (Stimuplex® HNS 11; B. Braun Melsungen AG, Melsungen, Germany). Insulated short-beveled needles (Mini Set®; Pajunk, Geisingen, Germany; or Contiplex®; B. Braun Melsungen AG) were connected to the nerve stimulator. The placement of the needle was considered successful when a specific muscle contraction was obtained with a current output of less than 0.5 mA (frequency 1 Hz and impulse duration 100 μs). The catheter was then inserted from 3 to 15 cm. The catheter was secured with adhesive strips and a transparent adhesive dressing (Opsite®; Smith and Nephew Medical Ltd., Hull, England). After tests for endovascular placement (aspiration, injection of 2 ml lidocaine, 2%, with 1:200,000 epinephrine), analgesia was induced with 0.5% ropivacaine (25–40 ml), 0.375% bupivacaine, or 1.5% mepivacaine for induction of the CPNB. Difficulties in catheter placement were recorded in terms of one attempt (*i.e.*, insertion of the catheter after the nerve location with the initial needle direction), two attempts, or more than two attempts.
- Postoperative analgesia was provided by continuous perineural infusion, by perineural patient-controlled analgesia with or without continuous infusion, or by bolus administration of 0.2% ropivacaine or 0.25% bupivacaine three times a day. Each participating anesthesiologist chose the method of administration and the local anesthetic used (appendix 2). The continuous infusions were run from 2 to 7 days.

The patient's arrival in the postanesthesia care unit (PACU) (or the end of catheter insertion for the patients who had postoperative CPNB) was considered to be hour 0. The following prospective data were collected by the physicians at hour 1 and then every 24 h until the fifth postoperative day: (1) Sensory blockade was evaluated using cold perception tests. (2) Motor blockade was evaluated by using a motor scale (0 = normal movement of the extremity, 1 = contraction of the muscles with moderately impaired movement of the extremity, 2 = muscle contractions but no movement possible, 3 = no movement and incapable of muscle contraction). (3) Pain at rest and during movement was evaluated using a visual analog scale (VAS) ranging from 0 (no pain) to 100 mm (worst imaginable pain). Throughout the study period, ketoprofen (100 mg twice daily) was administered when requested by the surgeon. If pain control was considered insufficient (VAS > 30 mm), 2 g intravenous propacetamol was administered over a 15-min period as the first step of rescue analgesia. If the VAS value remained greater than 30 mm at 30 min after the infusion of propacetamol, a subcutaneous injection of morphine (0.1 mg/kg) was administered as the second step of rescue analgesia. If insufficient, the rate of the continuous or background infusion was increased by 2 ml/h as the third step of rescue analgesia. If these measures were insufficient, analgesia provided by the CPNB was considered a failure. (4) Noninvasive monitor values of blood pressure and heart rate were continuously noted in the PACU, and heart rate and respiratory rate were noted three times a day in the surgical ward, as was use of intravenous cefamandole (750 mg four times a day). This follow up was necessary to detect adverse events. (5) Each patient was examined and questioned about the localization of adverse events by a member of the anesthesiology staff. Systemic adverse events, including arterial hypotension (decrease of 40% or more in the baseline mean arterial pressure), sedation, urinary retention, pruritus, acute respiratory failure, and local anesthetics systemic toxicity were distinguished from local adverse effects, which included hematoma, catheter-related problems, and aspiration of blood. Continuous motor blockade (numbness to paralysis) and sensory blockade (hypoesthesia to anesthesia) during or after CPNB as well as paresthesia or dysesthesia were noted. If neurologic adverse events (dysesthesia, paresthesia, continuous motor and sensory blockade) occurred at the 24-h assessments, the infusion of local anesthetics was discon-

tinued, and the patient was reexamined 2 h later. In the postoperative period, a suspected neurologic complication (neurologic deterioration, allodynia, or severe pain) was investigated by ultrasonography (Sonoline Omnia®; Siemens corporation, Germany) to exclude hematoma and by conventional electroneuromyography (Keypoint 4, Dentec, Denmark). The first electroneuromyography was performed 6–12 h after the observation of the neurologic complication. Electroneuromyography was repeated at 2 weeks, 6 weeks, and 3 months, if necessary. (6) At the end of the CPNB period, catheters were carefully and aseptically removed, and 5 cm of the distal extremity was cut and quantitatively cultured within 1 h using a modified technique for intravascular catheters.[16] The tip of the catheter was vigorously vortexed for 1 min in 1 ml saline, 0.9%; 0.1 ml of this suspension was withdrawn with a calibrated pipette and plated onto an agar-coated Petri dish. Two media were inoculated: trypticase soy agar and 5% horse blood agar. Plates were incubated at 37°C under aerobic conditions. All colony types were counted at 24, 48, and 72 h and identified by standard methods and criteria. Perineural catheter colonization was defined as the growth of at least one microorganism on quantitative CPNB catheter culture regardless of the colony-forming unit count. The insertion site of the catheter was checked twice a day by a nurse for local signs of infection. In case of signs of local inflammation (cellulitis or edema of the insertion site), pus, and fever temperature greater than 38.5°C, ultrasonography and computed tomography were performed to look for an abscess. If shivering and a leukocyte count greater than 10,000/mm^3 were present, blood cultures were also performed.

Statistical Analysis

The number of subjects necessary for the current study was estimated based on epidemiologic studies of postoperative epidural analgesia. The incidence of adverse events including infection, failure of the technique, neural lesions, and local anesthetic toxicity was anticipated to be 5%. Using an α value of 0.05, it was estimated that 811 patients would have to be included to determine the incidence of the adverse events with a precision of 1.5%.

Descriptive Statistics. First, an overall description of each of the recorded variables was performed. For the quantitative variables, this included calculation of the average, SD, minimum, first quartile, median, third quartile, and maximum. For each of the quantitative variables, the Gaussian character of the distribution was assessed using a Shapiro-Wilk test. For each CPNB modality, we determined the percentages of the qualitative variables and the percentages of the adverse events along with calculation of 95% confidence intervals.

Analytical Statistics. Analgesic efficacy (VAS scale) was assessed using a nonparametric Friedman test. When a significant difference was found, the values were compared using the Wilcoxon test for paired series. A two-step search for risk factors for adverse events or complications was conducted:

- Bivariate analysis was done using a chi-square test or a Fisher exact test (when the chi-square test was not valid), the strength of the correlation being assessed using a simple odds ratio.
- A logistic regression model was then applied to calculate adjusted odds ratios. A value of 0.20 was chosen for the entry threshold of the variables in the model, and the same value was used for the exit threshold. The validity of the model was verified using the maximum probability method.

For all analyses, $P < 0.05$ was used to determine significance.

The statistical analysis was performed using SAS software (version 6.12; SAS Institute, Cary, NC) in the Medical Computer Programming Department of the University Hospital of Montpellier, France.

Results

During the study, 1,422 patients—912, 440, and 70 patients with American Society of Anesthesiologists physical status I, II, and III, respectively—were included. Complete data were collected for 1,416 patients—797 women (56.3%) and 632 men (44.6%). Six patients were excluded after placement of the catheter (initial failure). The average age of the patients was 54.9 ± 18.5 yr (range, 18–97 yr). The average weight was 72.4 ± 15.2 kg (range, 33–165 kg); the average height was 167 ± 9 cm (range, 126–197 cm). Of the 1,416 patients, 1,393 (98%) were transferred from the PACU to the surgical wards, and 23 (2%) were initially monitored in an intensive care unit (range, 8 h to 4 days) before transfer to the ward.

Surgical Indications and Drugs Used for CPNB

The surgical indications are listed by category in table 1 along with the type of block used for these indications. The average duration of surgery was 117 ± 71 min (range, 15–700 min). General anesthesia was used with the CPNB for patient comfort during surgery in 1,042 of the patients (73.6%). Among the 374 patients scheduled to undergo only a perineural block with or without sedation (propofol and sufentanil bolus), 12 (3.2%) had general anesthesia because of pain during surgery. During the CPNB placement, 126 patients (12%) were anesthetized. CPNB was performed preoperatively in 1,064 patients (75%) and postoperatively in 352 patients (25%) as soon as they were taken to the PACU. Difficulties in placing the catheter (more than two attempts) were reported in 80 patients (5.6%). The local anesthetic chosen for induction of the CPNB was 0.5% ropivacaine in

Table 1. Surgical Indications and CPNB Performed

	Interscalene	Axillary	PCB	Femoral	Fascia I	Sciatic	Popliteal	Distal	Total	GA
Shoulder	223	0	0	0	0	0	0	0	223	185 (83%)
Rotator cuff repair										
Acromioplasty										
Arthroplasty										
Bankart										
Elbow	7	41	0	0	0	0	0	0	48	30 (62.5%)
Arthroplasty										
Arthrolysis										
Trauma										
Hand	0	76	0	0	0	0	0	38	114	47 (41.2%)
Major trauma										
Hip	0	0	18	125	12	7	0	0	162	144 (88.9%)
Arthroplasty										
Arthrolysis										
Osteotomy										
Neck fracture										
Knee	0	0	0	486	73	16	0	0	575	431 (75%)
Arthroplasty										
Arthrolysis										
Ligament repair										
Osteotomy										
Patella trauma										
Foot	0	0	0	0	0	0	155	0	155	90 (58%)
Trauma										
Hallux valgus										
Arthrodesis										
Other*	26	9	2	72	9	9	12	0	139	115 (82.7%)
Total	256 (18.1%)	126 (8.9%)	20 (1.4%)	683 (48.2%)	94 (6.6%)	32 (2.2%)	167 (11.8%)	38 (2.7%)	1,416	1,042 (73.6%)

* Surgery for of the upper arm, lower arm, or tibia.

Axillary = axillary catheter; Bankart = Bankart procedure; CPNB = continuous peripheral nerve block; Distal = distal nerve block catheter (cubital or median nerve); Fascia I = fascia iliaca compartment block catheter; Femoral = femoral catheter; GA = general anesthesia associated with continuous peripheral nerve block for the procedure; Interscalene = catheter of the brachial plexus through interscalene approach; PCB = catheter in the lumbar plexus through a posterior approach; Popliteal = popliteal catheter; Sciatic = sciatic catheter through a parasacral approach.

57.8% of the patients, 0.375% bupivacaine in 30.0% of the patients, and 1.5% mepivacaine in 12.2% of the patients. For postoperative analgesia, 0.2% ropivacaine was chosen in 62.5% of the patients, and 0.25% bupivacaine was used in the other 37.5% of the patients. The average time the catheter remained in place was 56 h (25th percentile: 46 h; 75th percentile: 81 h).

Efficacy of CPNB

The VAS pain scores at rest and during movement in the postoperative period are presented in figure 1. In the postoperative period, the median values of the VAS at rest and during movement were less than 25 mm. There was an increase in pain at 24 h, both at rest and during movement of the operated extremity ($P < 0.05$). Twen-

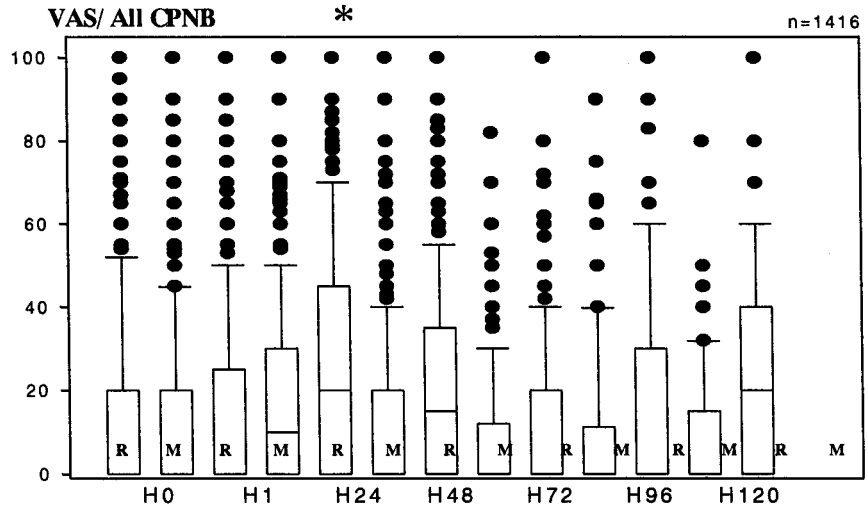

Fig. 1. Values of visual analog pain scale (VAS) scores at rest (R) and during movement (M) in all the patients in the postoperative period. The *box* represents the 25th–75th percentiles. The *dark line* is the median. The *extended bars* represent the 10th–90th percentiles, and the *dark circles* represent the values outside this range. CPNB = continuous peripheral nerve block. * $P < 0.05$, hour 24 *versus* other times.

Table 2. Incidence of Serious Adverse Events in All CPNB Groups

Serious Adverse Events	n (%) among the Selected CPNBs [95% CI]							
	Interscalene (n = 256)	Axillary (n = 126)	PCB (n = 20)	Femoral (n = 683)	Fascia I (n = 94)	Sciatic (n = 32)	Popliteal (n = 167)	Distal (n = 38)
Patients (n)	4	1	3	3	0	0	0	1
Nerve lesions	0	0	0	3 (0.4) [0.1–0.9]	0	0	0	0
Acute respiratory failure	2 (0.8) [0.2–2.1]	0	0	0	0	0	0	0
Laryngeal and recurrent laryngeal nerve paralysis	2 (0.8) [0.3–1.8]	0	0	0	0	0	0	0
Severe hypotension	0	0	3 (15) [4–31.3]	0	0	0	0	0
Systemic LA toxicity	0	0	0	0	0	0	0	1 (2.5) [0.3–3.7]
Seizure	0	1 (0.8) [0.05–1.3]	0	0	0	0	0	0
Abscess	0	0	0	1 (0.14) [0.01–0.8]	0	0	0	0

Axillary = axillary catheter; CI = confidence interval; CPNB = continuous peripheral nerve block; Distal = distal nerve block catheter (cubital or median nerve); Fascia I = fascia iliaca compartment block catheter; Femoral = femoral catheter; Interscalene = catheter of the brachial plexus through interscalene approach; LA = local anesthetics; PCB = catheter in the lumbar plexus through a posterior approach; Popliteal = popliteal catheter; Sciatic = sciatic catheter through a parasacral approach.

ty-five percent of the patients received morphine at day 0, 16% at day 1, and less than 10% up to day 5.

Adverse Events and Risk Factors for Side Effects during CPNB

There were 394 (28%) minor adverse events noted in the postoperative period. However, these events were mostly accounted for by 253 (17.9%) technical problems with catheters and devices (kinked catheter, catheter withdrawn inadvertently, displaced catheter, blocked catheter, leakage of the local anesthetic around the catheter, unwanted stopping of the electric pump, alarms for no reason, and others). Accidental withdrawal of the catheter was the most frequent incident (10.5%). The anesthesiologist resolved 80.5% of the minor adverse events the day they occurred. In forty-one patients (2.9%), blood appeared in the catheter during placement. Forty-two patients (3%) had persistent sensory blockade, 31 (2.2%) had persistent motor blockade, and 21 (1.5%) had paresthesias or dysesthesias during CPNB in the postoperative period. Forty-seven patients (3.3%) experienced failure of pain relief.

Twelve serious adverse events (0.84%) directly related to CPNB were noted (table 2). All events resolved without sequelae. Two patients with continuous interscalene blocks had diaphragmatic paralysis with acute respiratory failure. They were admitted to the intensive care unit in the postoperative period. Two other interscalene block patients had symptomatic laryngeal and recurrent nerve paralysis with impairment of swallowing. Three patients with continuous psoas compartment blocks developed an epidural anesthesia with hemodynamic instability associated with the initial injection. One intravenous catheter migration detected at 24 h without systemic toxicity and one case of epileptic seizure were noted. Three femoral nerve lesions (0.21%) were attributed to CPNB. Two of the three continuous femoral nerve blocks were performed in anesthetized patients, and the third patient reported sharp pain upon injection of the induction bolus of local anesthetic. Computed tomography did not show nerve hematoma in these three patients, whereas electroneuromyography showed decreases in latencies and amplitudes in the femoral nerve of two. The patient with no electromyographic evidence of nerve injury had complete resolution of symptoms in 36 h. In the two patients with electromyographic changes, signs of regeneration (fasciculation potentials) were noted at 6 weeks. One of the latter patients had complete resolution of symptoms at 8 weeks, and the other had complete resolution at 10 weeks. One common peroneal nerve lesion occurred in a patient with a femoral catheter and a single-shot sciatic nerve block. It was due to a common peroneal nerve hematoma. This nerve injury was not attributed to the CPNB.

Among 969 catheters (68%) submitted to culture studies, 278 had positive bacterial colonization (28.7%), with a single organism in 242 cases. The bacterial species most frequently found were coagulase-negative staphylococcus (*Staphylococcus epidermidis*; 61%), gram-negative bacillus (21.6%), and staphylococcus aureus (17.6%) (table 3). *Staphylococcus epidermidis*–positive cultures were found in 83% of interscalene catheters. Among the catheters used for distal nerve blocks, *Staphylococcus aureus* was found in 8.7%. Cultures were positive for gram-negative bacillus in 42.7% of the tested fascia iliaca compartment block catheters (table 4). The incidence of local inflammatory

Table 3. Results of Catheter Culture Analysis and Incidence of Colonization

	n	%
Gram-negative bacilli	58	22
Escherichia coli	15	4.8
Enterobacter cloacae	11	3.5
Pseudomonas aerogenes	9	2.9
Klebsiella pneumoniae	8	2.6
Proteus mirabilis	8	2.6
Acinetobacter	7	2.3
Citrobacter	4	1.3
Serratia	3	1
Other	3	1
Gram-positive cocci	237	76.4
Coagulase-negative staphylococcus	195	62.9
Staphylococcus aureus	15	4.8
Enterococcus	21	6.8
Other	6	1.9
Gram-positive bacilli	4	1.3
Other	1	0.3

signs (focal pain, redness, induration) was 3%. In these patients, 44.2% of the catheters were colonized, whereas 18.6% of catheters were colonized in patients without inflammatory signs ($P = 0.001$). There was no correlation between fever and bacterial colonization of the catheter. One case of psoas muscle abscess and cellulitis was noted in a diabetic woman who had a femoral catheter after a total knee replacement. After removing the catheter, cultures showed *Staphylococcus aureus*, and the patient recovered with a targeted antibiotic treatment. No bacteremia was found.

Independent risk factors for neurologic and infectious adverse events were identified using logistic regression (multivariate analysis) and are reported in table 5. Risk factors for paresthesia, dysesthesia, or continuous motor/sensory blockade were postoperative monitoring in intensive care (relative risk [RR] 9.8), age 18–39 yr (RR 3.9), and use of bupivacaine (RR 2.8). Risk factors for local inflammation or infection were postoperative monitoring in intensive care (RR 5.07), catheter duration longer than 48 h (RR 4.61), male sex (RR 2.1), and absence of prophylactic use of antibiotics (RR 1.92).

Discussion

This multicenter prospective study shows that the use of CPNBs by very highly trained anesthesiologists following standardized insertion techniques is associated with a high quality of postoperative analgesia and a low rate of acute neurologic or infectious complications in the postoperative period.

Some results of the study deserve comments. The numbers of CPNBs recorded in all the institutions were not similar, but the distributions of the types of regional techniques used were not different between the institutions. A weakness in the design of the study is that anesthesiologists placing the CPNB and presumably interested in demonstrating the efficacy and low complication rates performed the follow up. This lack of blinding and the potential for bias must be taken into account. Finally, the conclusions regarding the quality of postoperative analgesia remain limited by the study design: no comparison groups, multiple initial solutions, and various postoperative infusions.

Technical Characteristics of CPNB

Continuous peripheral nerve block has become the technique of choice for the management of postoperative pain primarily in open shoulder and knee procedures and foot surgery.[2–5,13–15] One should note that, from the standpoint of the anesthesiologists, CPNB served essentially to optimize postoperative analgesia and rehabilitation, explaining why 1,030 patients (72.5%) had planned general anesthesia in addition to CPNB. This result is consistent with the high percentage of combined use reported in many studies.[9,10,12,14,17,18]

Table 4. Results of Catheter Culture for Each CPNB Group

	Interscalene (n = 256)	Axillary (n = 126)	PCB (n = 20)	Femoral (n = 683)	Fascia I (n = 94)	Sciatic (n = 32)	Popliteal (n = 167)	Distal (n = 38)
Catheters with culture, (n) %	(n = 166) 64.9	(n = 77) 61.1	(n = 15) 76.9	(n = 485) 71.1	(n = 65) 69.3	(n = 25) 77.4	(n = 112) 67.5	(n = 24) 63.3
Colonized catheters, % [95% CI]	25.6 [19–32]	36.5 [25.5–47.4]	20 [2.4–37.5]	28.6 [14.9–52.2]	28.6 [14.9–42.2]	30.4 [11.6–49.2]	18.9 [11.6–26.2]	35.5 [24–47.4]
Organisms, %								
Coagulase-negative staphylococcus	83	56.7	66.7	52.3	35.7	75	77.3	69.6
SA	4.3	6.7	0	4.6	7.1	0	0	8.7
Enterococcus	2.1	3.3	0	9.9	14.3	12.5	0	0
Other gram-positive cocci	6.4	3.3	0	1.3	0	0	0	0
Gram-negative bacillus	0	26.7	33.3	27.1	42.7	12.5	18.1	21.7
Others	4.2	6.6	0	4.8	0.2	0	4.6	0

Axillary = axillary catheter; CI = confidence interval; CPNB = continuous peripheral nerve block; Distal = distal nerve block catheter (cubital or median nerve); Fascia I = fascia iliaca compartment block catheter; Femoral = femoral catheter; Interscalene = catheter of the brachial plexus through interscalene approach; PCB = catheter in the lumbar plexus through a posterior approach; Popliteal = popliteal catheter; SA = *Staphylococcus aureus*; Sciatic = sciatic catheter through a parasacral approach.

Table 5. Risk Factors* for Side Effects with CPNB

Side Effect	Risk Factor	Odds Ratio [95% CI]	*P* Value
Neurologic adverse events			
Dysesthesia/paresthesia	Intensive care unit	9.8 [2.02–38.5]	**0.004**
	Patient age < 40 yr	3.9 [1.6–9.8]	**0.006**
	Bupivacaine infusion	2.7 [1.06–6.8]	**0.02**
	CPNB duration > 48 h	0.98 [0.81–1.3]	0.13
	Male sex	1.1 [0.83–3.2]	0.18
	Female sex	1.15 [1–5.2]	0.21
	Continuous infusion technique	1.2 [0.75–8.2]	0.09
	BMI > 30 kg/m^2	1.3 [0.8–8.2]	0.13
Sensory/motor blockade	Bupivacaine infusion	3.8 [1.7–7.8]	**0.008**
Infectious adverse events			
Local infection/inflammation	Intensive care unit	5.07 [0.33–18.1]	**0.004**
	CPNB duration > 48 h	4.61 [1.57–15.9]	**0.008**
	Male sex	2.1 [1.07–4.1]	**0.008**
	No antibiotic prophylaxis	1.92 [1.03–3.9]	**0.01**
	Bupivacaine infusion	1.3 [0.67–2.7]	0.12
	Preoperative	1.2 [0.78–5.9]	0.23
	Multiple bolus technique	1.3 [0.98–10.7]	0.09
	BMI > 30 kg/m^2	1.2 [0.93–11]	0.21

* Risk factors determined using logistic regression (multivariate analysis).

Bupivacaine infusion *versus* ropivacaine infusion; continuous infusion technique *versus* multiple bolus technique or patient-controlled analgesia technique; preoperative *versus* postoperative. Bold values are statistically significant.

BMI = body mass index; CI = confidence interval; CPNB = continuous peripheral nerve block; Intensive care unit = patient admitted postoperatively to an intensive care unit *versus* to orthopedic surgery wards; Patient age < 40 yr = patients aged 20–40 yr *versus* older than 40 yr (age range 40–60 yr and 60–80 yr).

The use of CPNB for both anesthesia and analgesia led to general anesthesia in 3.2% of the patients in the current series. It is a quite high percentage of unplanned general anesthesia after the regional anesthesia technique. Some anesthesiologists did not wait a sufficient time to obtain a complete sensory blockade or had a wrong appreciation of the surgical territory according to the selected regional anesthesia technique or there were some changes in the surgical procedure in the operating room. This percentage confirms previous findings in the literature. Borgeat *et al.*[12] reported 3.9% of patients receiving general anesthesia because of pain during surgery.

Our percentage of catheter placement with difficulty (5.6%) was low with respect to previous reports, even though the difficulties in perineural catheter insertion reported by various authors clearly seem to be correlated to the site of catheter placement. Difficulties inserting the catheter have been reported by Singelyn *et al.*[19] in 66% of continuous interscalene blocks, by Tuominen *et al.*[20] in up to 25%, and by Borgeat *et al.*[12] in 6%. Insertion problems were encountered in 9.5% of femoral nerve catheters by Cuvillon *et al.*[10] and in 5% by Singelyn and Gouverneur.[9]

Quality of Postoperative Analgesia

The postoperative analgesia achieved using CPNB was good in the current study, confirming results from the majority of studies in the literature.[2–23] The improved analgesia provided by CPNBs has been reported to result in faster short-term functional recovery during rehabilitation than that provided by intravenous patient-controlled analgesia, although there was no significant difference in results after 6–12 weeks.[4,5] Complete pain relief in the early postoperative period remains, however, difficult to achieve even with continuous administration of local anesthetics in CPNB. According to some authors, even if good postoperative analgesia is achieved, pain is difficult to control in the first 2 postoperative days.[3,10,14,17,19] It is noteworthy that, in our study, there was a significant increase in both pain at rest and during movement at 24 h. This increase in the median VAS pain scores at 24 h, widely reported[3,10,14,17,19] but rarely discussed, warrants comment. One of the primary reasons is that the maximal effect was achieved with the induction solution of local anesthetic. The volume of the anesthetic solution induces a complete anesthesia that is difficult to maintain postoperatively with limited continuous infusion of low concentrations of local anesthetic. Barthelet *et al.*[24] showed that a block of the lumbar plexus does not persist after the initial bolus effect of local anesthetic despite continuous infusion of lidocaine through a femoral catheter. The analgesia was subsequently limited to the femoral nerve. The high VAS scores with the femoral catheters are explained by the absence of analgesic block of the territories of the sciatic or obturator nerves or both. The improvement of the levels of postoperative analgesia with a separate block of these nerves is demonstrated currently.[25,26] However, rapid and appropriate management by nurses in the PACU using rescue analgesia has been shown to optimize pain relief. The use of rescue analgesia by nurses of the surgical ward may have been

less systematic, contributing to the higher level of pain at 24 h. The quality of the current combination of analgesic techniques has been clearly demonstrated by our findings. The patients needed little rescue analgesia, and the number of patients requiring it rapidly decreased. Regarding a series of 228 CPNBs for ambulatory surgical procedures, Grant *et al.*[14] reported percentages of patients requiring morphine close to those that we observed. In our study, with the exception of the PACU, where use of morphine was rare (10.9%), 59–80% of the patients required oral or intravenous narcotics one time during the first 24 h.

Side Effects and Risk Factors for Complications

The percentage of technical problems due to catheters and devices (17.9%) might seem high, but this value is consistent with the literature.[7,8,27] Bergman *et al.*[8] reported 7.7% of technical difficulties with CPNB. Klein *et al.*[28,29] observed between 9% and 44% of technical problems with continuous interscalene blocks. It should be noted that 80% of the current technical problems were resolved the day they occurred by the anesthesiologist in charge of the patient. However, in the postoperative period, persistent sensory and motor blockades were noted in 3% and 2.2% of patients, respectively, and paresthesias were reported by 1.5% of our patients. The overall incidence of these neurologic adverse events in the current study was 6.6%, a value quite close to the 8% reported by Borgeat *et al.*[12] in the first 10 days after continuous interscalene block.

Neurologic damage is a major concern during and after CPNB. The frequency of peripheral neurologic complications after single-shot peripheral nerve block is not well established. Auroy *et al.*[30] reported 4 neural lesions among 21,278 peripheral nerve blocks (0.02%). More recently, the same group[31] reported 12 neural lesions among 50,223 peripheral nerve blocks (0.02%). The deficit persisted in 7 of the latter patients 7 months after the blocks. The incidence of neural injuries in the latest study ranged from 0.03% of femoral blocks to 0.31% of popliteal nerve blocks. Among 3,996 peripheral nerve blocks, Fanelli *et al.*[32] recorded 69 neural lesions (1.7%), all of which improved within 4–12 weeks. Regarding CPNB, Horlocker *et al.*[33] observed 0.4% of neural lesions out of 1,614 axillary blocks. Other sources have cited 0.1% of neural lesions involving femoral catheters,[9] 4 cases (1%) of postoperative neurologic deficit in a series of 405 axillary catheters,[8] and no cases in a group of 228 patients.[14] The overall occurrence of postoperative neurologic deficit (0.21%) due to CPNB in our study was comparable to the incidence (0.2%) observed by Borgeat *et al.*[12] in 700 continuous interscalene blocks. More precisely, 3 neural lesions among 683 continuous femoral nerve blocks (0.4%) were found. This number was similar to that found by Cuvillon *et al.*,[10] who noted 1 case of femoral nerve damage partially resolved at 1 yr in a series of 211 femoral catheters (0.4%). Elements regarding these femoral nerve lesions are noteworthy: Two of the patients involved had the block while already under general anesthesia. The use of a nerve stimulator is not a guarantee against accidental intraneural injection despite the absence of a motor response.[34] One of the 3 patients experienced sharp pain during the injection of local anesthetics. This is reminiscent of cases reported by Auroy *et al.*[30,31] The injection of local anesthetics was accompanied by pain or paresthesias in all of their patients who had nerve damage. Another factor to consider was the use of 0.25% bupivacaine and 1:200,000 epinephrine in some of the current patients, given reports that these two agents could contribute to ischemia and neural toxicity.[35] Furthermore, there is also a risk of nerve lesions associated with the surgical procedures themselves. After total hip arthroplasty without peripheral nerve block, the reported incidence of femoral nerve injury is between 0.1% and 0.4%,[36] and the occurrence of all observed nerve lesions in such patients ranges from 0.7% to 3%.[37]

Two continuous interscalene blocks were complicated by respiratory insufficiency (lower lobe collapse). These complications are not surprising. Ipsilateral diaphragmatic paralysis is constant during interscalene blocks[38] and persists throughout the infusion of local anesthetics.[39] Respiratory impairment observed during the use of continuous interscalene blocks have, in some cases,[38,39] led to urgent rehospitalization of the patient.[40] Three of our patients had epidural diffusion of local anesthetics after a continuous psoas compartment block with decrease of greater than 40% in baseline mean arterial pressure. The patients were successfully treated with rapid infusion of colloids without vasopressors. The reported incidence of epidural diffusion ranges from 5% to 6.5% in continuous psoas compartment blocks.[41,42] Epidural or spinal spread of local anesthetics can lead to severe hypovolemic shock and death.[31]

Continuous perineural catheter infection is an issue that has received little attention to date. We reported one case of psoas muscle abscess and cellulitis in one diabetic woman. The patient was successfully treated with antibiotics. Severe infectious complications recently reported elsewhere include a psoas abscess complicating a continuous femoral nerve block,[43] an abscess of the axilla[8] and a necrotizing fasciitis[44] after continuous axillary nerve blocks, and an interscalene abscess after a continuous interscalene block.[12] It is interesting to note that, in three of the latter five cases, *Staphylococcus aureus* was identified, and three of the five patients had diabetes mellitus. We found a colonization rate of 28%. Three percent of our patients had signs of local inflammation. Recently, Cuvillon *et al.*[10] prospectively reported an incidence of 57% of colonized femoral catheters, 1.5% with bacteremia, after 48 h of continuous infusion of bupivacaine or ropivacaine. Simpson *et al.*[45] reported a colonization incidence of 28.8% in 1,443

epidural catheters placed postoperatively. They found a colonization rate of 13% in the subgroup of patients who had orthopedic operations, with an average indwelling catheter duration of 36 h. Similarly to studies focused on epidural catheter colonization,[45–47] we noted that the coagulase-negative staphylococcus was the most frequently isolated bacteria from the CPNB catheters. In accordance with Borgeat *et al.*[12] and Cuvillon *et al.*,[10] coagulase-negative staphylococcus was primarily found in interscalene and popliteal catheters, enterococcus and gram-negative bacilli were found in axillary and femoral catheters, and *Staphylococcus aureus* was found in distal nerves catheters. The predominance of coagulase-negative staphylococcus at the perineural catheter tip in the current study is not surprising, nor was the presence of gram-negative bacilli in the axillary and femoral catheters. We believe that this probably represents colonization of the skin at the catheter insertion site and subsequent contamination of the catheter tip on removal of the catheter despite aseptic conditions. This hypothesis is supported by the fact that 44.2% of the catheters with signs of local inflammation were colonized as opposed to only 18.6% of the catheters with no evidence of local inflammation. Similarly, Darchy *et al.*[46] found no positive cultures from epidural catheters when signs of local inflammation were absent, whereas 15% of the cultures were positive in the presence of local inflammation. Furthermore, Sato *et al.*[47] showed that regardless of the antiseptic used, all protocols were insufficient against *Staphylococcus epidermidis* during the use of epidural catheters. Fortunately, the very low number of infections (0.07%) despite the large number of "positive-culture" tips is reassuring.

Logistic regression analysis was used to identify independent risk factors for paresthesia, numbness, hypoesthesia, and local infection. The very low incidence of abscess and nerve lesions among the 1,416 patients hindered identification of risk factors for these serious complications. The strongest risk factor for development of the studied neurologic and infectious adverse events was intensive care unit hospitalization. These patients, most of whom were trauma victims, were probably more sensitive to neural ischemia due to intermittent arterial hypotension, anemia, and/or hypoxia during the perioperative period. Moreover, compromised cellular immunity, which develops frequently in intensive care patients, might have contributed to the higher risk of infection. Rygnestad *et al.*[48] reported two epidural abscesses among 2,000 postoperative epidural analgesias in surgical wards, both of which involved trauma patients in intensive care unit. The use of bupivacaine was a risk factor for paresthesia/dysesthesia occurrence. Rawal *et al.*[49] reported 29% of patients having numbness of fingers during continuous infusion of 0.125% bupivacaine in axillary catheters as opposed to only 6.9% of patients with 0.125% ropivacaine. Similarly, Borgeat *et al.*[50] reported finger paresthesias in 93%, 76%, and 37% of patients at hours 24, 48, and 54, respectively, during interscalene infusion of 0.15% bupivacaine *versus* 73%, 50% and 0%, respectively, in those who had 0.2% ropivacaine infusion. CPNB duration (> 48 h) was a strong risk factor for local infectious problems. This finding is consistent with studies having reported a correlation between the duration of the indwelling catheter and the incidence of colonization or local infection involving epidural catheters.[45,46] Also in our study, the absence of antibiotic prophylaxis was an independent risk factor for local inflammation. Although this risk is understandable, to the best of our knowledge, its correlation has never before been demonstrated for epidural or perineural catheter use. Bergman *et al.*[8] reported an axillary infection after a CPNB in a patient who did not receive the usual 2 days of antibiotic therapy. These authors emphasized that this absence of antibiotics might have a played a role. In conclusion, CPNB is an efficacious technique for postoperative analgesia. Technical incidents and the colonization of the catheters are frequent but without clinical repercussion in the large majority of cases. Rare severe neurologic and infectious adverse effects are possible.

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Appendix 1

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Appendix 2: Amounts of Local Anesthetics Used According to the Site of Perineural Catheter Placement and Technique of Continuous Infusion

	Continuous Infusion	PCA + BI	PCA	Bolus—Physician
IS	5–7 ml/h	3 ml/h; 4-ml bolus	5 ml every h	15 ml every 8 h
AX	5–7 ml/h	3 ml/h; 4-ml bolus	5 ml every h	15 ml every 8 h
PCB	8 ml/h	3 ml/h; 5-ml bolus	5–8 ml every h	15 ml every 8 h
F/FI	7–12 ml/h	5 ml/h; 5- to 7-ml bolus	8–10 ml every h	20 ml every 8 h
Sc	5–8 ml/h	3 ml/h; 5-ml bolus	5–8 ml every h	15 ml every 8 h
Pop	5–7 ml/h	3 ml/h; 4-ml bolus	5 ml every h	15 ml every 8 h
Distal	3–5 ml/h	2 ml/h; 3-ml bolus	5 ml every h	8 ml every 8 h

Ax = axillary catheter; Bolus—physician = bolus of local anesthetics by the physician in surgical wards; Distal = distal catheter (elbow); F/FI = femoral and fascia iliaca compartment block catheter; IS = interscalene catheter; PCA = patient-controlled analgesia bolus only; PCA + BI = patient-controlled analgesia plus background continuous infusion; PCB = psoas compartment block catheter; Pop = popliteal sciatic nerve block catheter; Sc = sciatic nerve catheter.