UNIVERSITE D'ANGERS

FACULTE DE MEDECINE

Année 2013 **N°……….**

THESE

pour le

DIPLOME D'ETAT DE DOCTEUR EN MEDECINE

Qualification en : ANESTHESIE-REANIMATION

Par

Emmanuel RINEAU

Né le 26 novembre 1982 à Angers

Présentée et soutenue publiquement le : lundi 21 octobre 2013

COURBES D'APPRENTISSAGE DES INTERNES POUR LA PRATIQUE DE L'ANESTHESIE LOCO-REGIONALE SOUS ECHOGRAPHIE
ETUDE CAPPRI

Président : Monsieur le Professeur Sigismond LASOCKI

Directeur : Monsieur le Docteur Naren SCHINKEL

LISTE DES ENSEIGNANTS DE LA FACULTÉ DE MÉDECINE D'ANGERS

Doyen	Pr. RICHARD
Vice doyen recherche	Pr. BAUFRETON
Vice doyen pédagogie	Pr. COUTANT

Doyens Honoraires : Pr. BIGORGNE, Pr. EMILE, Pr. REBEL, Pr. RENIER, Pr. SAINT-ANDRÉ

Professeur Émérite : Pr. Gilles GUY, Pr. Jean-Pierre ARNAUD

Professeurs Honoraires : Pr. ACHARD, Pr. ALLAIN, Pr. ALQUIER, Pr. BASLÉ, Pr. BIGORGNE, Pr. BOASSON, Pr. BOYER, Pr. BREGEON, Pr. CARBONNELLE, Pr. CARON-POITREAU, Pr. M. CAVELLAT, Pr. COUPRIS, Pr. DAUVER, Pr. DELHUMEAU, Pr. DENIS, Pr. DUBIN, Pr. EMILE, Pr. FOURNIÉ, Pr. FRANÇOIS, Pr. FRESSINAUD, Pr. GESLIN, Pr. GROSIEUX, Pr. GUY, Pr. HUREZ, Pr. JALLET, Pr. LARGET-PIET, Pr. LARRA, Pr. LIMAL, Pr. MARCAIS, Pr. PARÉ, Pr. PENNEAU, Pr. PIDHORZ, Pr. POUPLARD, Pr. RACINEUX, Pr. REBEL, Pr. RENIER, Pr. RONCERAY, Pr. SIMARD, Pr. SORET, Pr. TADEI, Pr. TRUELLE, Pr. TUCHAIS, Pr. WARTEL

PROFESSEURS DES UNIVERSITÉS

MM.	**ABRAHAM Pierre**	Physiologie
	ASFAR Pierre	Réanimation médicale
	AUBÉ Christophe	Radiologie et imagerie médicale
	AUDRAN Maurice	Rhumatologie
	AZZOUZI Abdel-Rahmène	Urologie
Mmes	**BARON Céline**	Médecine générale (professeur associé)
	BARTHELAIX Annick	Biologie cellulaire
MM.	**BATAILLE François-Régis**	Hématologie ; Transfusion
	BAUFRETON Christophe	Chirurgie thoracique et cardiovasculaire
	BEAUCHET Olivier	Médecine interne, gériatrie et biologie du vieillissement
	BEYDON Laurent	Anesthésiologie et réanimation chirurgicale
	BIZOT Pascal	Chirurgie orthopédique et traumatologique
	BONNEAU Dominique	Génétique
	BOUCHARA Jean-Philippe	Parasitologie et mycologie
	CALÈS Paul	Gastroentérologie ; hépatologie
	CAMPONE Mario	Cancérologie ; radiothérapie option cancérologie
	CAROLI-BOSC François-Xavier	Gastroentérologie ; hépatologie
	CHABASSE Dominique	Parasitologie et mycologie
	CHAPPARD Daniel	Cytologie et histologie
	COUTANT Régis	Pédiatrie
	COUTURIER Olivier	Biophysique et Médecine nucléaire
	DARSONVAL Vincent	Chirurgie plastique, reconstructrice et esthétique ; brûlologie
	de BRUX Jean-Louis	Chirurgie thoracique et cardiovasculaire
	DESCAMPS Philippe	Gynécologie-obstétrique ; gynécologie médicale
	DIQUET Bertrand	Pharmacologie fondamentale ; pharmacologie clinique
	DUVERGER Philippe	Pédopsychiatrie
	ENON Bernard	Chirurgie vasculaire ; médecine vasculaire
	FANELLO Serge	Épidémiologie, économie de la santé et prévention
	FOURNIER Henri-Dominique	Anatomie
	FURBER Alain	Cardiologie
	GAGNADOUX Frédéric	Pneumologie
	GARNIER François	Médecine générale (professeur associé)

MM.	**GARRÉ Jean-Bernard**	Psychiatrie d'adultes
	GINIÈS Jean-Louis	Pédiatrie
	GRANRY Jean-Claude	Anesthésiologie et réanimation chirurgicale
	HAMY Antoine	Chirurgie générale
	HUEZ Jean-François	Médecine générale
Mme	**HUNAULT-BERGER Mathilde**	Hématologie ; transfusion
M.	**IFRAH Norbert**	Hématologie ; transfusion
Mmes	**JEANNIN Pascale**	Immunologie
	JOLY-GUILLOU Marie-Laure	Bactériologie-virologie ; hygiène hospitalière
MM.	**LACCOURREYE Laurent**	Oto-rhino-laryngologie
	LASOCKI Sigismond	Anesthésiologie et réanimation ; médecine d'urgence option anesthésiologie et réanimation
	LAUMONIER Frédéric	Chirurgie infantile
	LE JEUNE Jean-Jacques	Biophysique et médecine nucléaire
	LE ROLLE Nicolas	Réanimation médicale
	LEFTHÉRIOTIS Georges	Physiologie
	LEGRAND Erick	Rhumatologie
Mme	**LUNEL-FABIANI Françoise**	Bactériologie-virologie ; hygiène hospitalière
MM.	**MALTHIÉRY Yves**	Biochimie et biologie moléculaire
	MARTIN Ludovic	Dermato-vénéréologie
	MENEI Philippe	Neurochirurgie
	MERCAT Alain	Réanimation médicale
	MERCIER Philippe	Anatomie
Mmes	**NGUYEN Sylvie**	Pédiatrie
	PENNEAU-FONTBONNE Dominique	Médecine et santé au travail
MM.	**PICHARD Eric**	Maladies infectieuses ; maladies tropicales
	PICQUET Jean	Chirurgie vasculaire ; médecine vasculaire
	PODEVIN Guillaume	Chirurgie infantile
	PROCACCIO Vincent	Génétique
	PRUNIER Fabrice	Cardiologie
	REYNIER Pascal	Biochimie et biologie moléculaire
Mme	**RICHARD Isabelle**	Médecine physique et de réadaptation
MM.	**RODIEN Patrice**	Endocrinologie et maladies métaboliques
	ROHMER Vincent	Endocrinologie et maladies métaboliques
	ROQUELAURE Yves	Médecine et santé au travail
Mmes	**ROUGÉ-MAILLART Clotilde**	Médecine légale et droit de la santé
	ROUSSELET Marie-Christine	Anatomie et cytologie pathologiques
MM.	**ROY Pierre-Marie**	Thérapeutique ; médecine d'urgence ; addictologie
	SAINT-ANDRÉ Jean-Paul	Anatomie et cytologie pathologiques
	SENTILHES Loïc	Gynécologie-obstétrique
	SUBRA Jean-François	Néphrologie
	URBAN Thierry	Pneumologie
	VERNY Christophe	Neurologie
	VERRET Jean-Luc	Dermato-vénéréologie
MM.	**WILLOTEAUX Serge**	Radiologie et imagerie médicale
	ZANDECKI Marc	Hématologie ; transfusion

MAÎTRES DE CONFÉRENCES

MM.	**ANNAIX Claude**	Biophysique et médecine nucléaire
	ANNWEILER Cédric	Médecine interne, gériatrie et biologie du vieillissement ; médecine générale ; addictologie option , gériatrie et biologie du vieillissement
Mmes	**BEAUVILLAIN Céline**	Immunologie
	BELIZNA Cristina	Médecine interne, gériatrie et biologie du vieillissement
	BLANCHET Odile	Hématologie ; transfusion
M.	**BOURSIER Jérôme**	Gastroentérologie ; hépatologie ; addictologie
Mme	**BOUTON Céline**	Médecine générale (maître de conférences associé)
MM.	**CAILLIEZ Éric**	Médecine générale (maître de conférences associé)
	CAPITAIN Olivier	Cancérologie ; radiothérapie
	CHEVAILLER Alain	Immunologie
Mme	**CHEVALIER Sylvie**	Biologie cellulaire
MM.	**CONNAN Laurent**	Médecine générale (maître de conférences associé)
	CRONIER Patrick	Anatomie
	CUSTAUD Marc-Antoine	Physiologie
Mme	**DUCANCELLE Alexandra**	Bactériologie-virologie ; hygiène hospitalière
MM.	**DUCLUZEAU Pierre-Henri**	Nutrition
	FORTRAT Jacques-Olivier	Physiologie
	HINDRE François	Biophysique et médecine nucléaire
	JEANGUILLAUME Christian	Biophysique et médecine nucléaire
Mme	**JOUSSET-THULLIER Nathalie**	Médecine légale et droit de la santé
MM.	**LACOEUILLE Franck**	Biophysique et médecine nucléaire
	LETOURNEL Franck	Biologie cellulaire
Mmes	**LOISEAU-MAINGOT Dominique**	Biochimie et biologie moléculaire
	MARCHAND-LIBOUBAN Hélène	Biologie cellulaire
	MAY-PANLOUP Pascale	Biologie et médecine du développement et de la reproduction
	MESLIER Nicole	Physiologie
MM.	***MOUILLIE Jean-Marc***	*Philosophie*
	PAPON Xavier	Anatomie
Mmes	**PASCO-PAPON Anne**	Radiologie et Imagerie médicale
	PELLIER Isabelle	Pédiatrie
	PENCHAUD Anne-Laurence	*Sociologie*
M.	**PIHET Marc**	Parasitologie et mycologie
Mme	**PRUNIER Delphine**	Biochimie et biologie moléculaire
M.	**PUISSANT Hugues**	Génétique
Mmes	**ROUSSEAU Audrey**	Anatomie et cytologie pathologiques
	SAVAGNER Frédérique	Biochimie et biologie moléculaire
MM.	**SIMARD Gilles**	Biochimie et biologie moléculaire
	TURCANT Alain	Pharmacologie fondamentale ; pharmacologie clinique

septembre 2012

COMPOSITION DU JURY

Président du jury :

Monsieur le Professeur Sigismond LASOCKI

Directeur de thèse :

Monsieur le Docteur Naren SCHINKEL

Membres du jury :

Monsieur le Professeur Laurent BEYDON

Monsieur le Professeur Jean-Claude GRANRY

Monsieur le Docteur Guillaume BOUHOURS

Monsieur le Docteur Naren SCHINKEL

REMERCIEMENTS

Mes remerciements vont

A Monsieur le Professeur Sigismond Lasocki
Qui me fait l'honneur de présider ce jury,
Pour ses conseils et sa disponibilité permanente,
Pour m'avoir initié et donné goût à la recherche expérimentale,
Et pour son encadrement dans mes projets universitaires de recherche et d'enseignement.

A Monsieur le Professeur Laurent Beydon
Qui me fait l'honneur de juger ce travail,
Pour son enseignement théorique et pratique de l'anesthésie-réanimation,
Et pour m'avoir conseillé à de nombreuses reprises au cours de ces années d'internat.

A Monsieur le Professeur Jean-Claude Granry
Qui me fait l'honneur de juger ce travail,
Pour m'avoir accueilli chaleureusement dans son service,
Et pour m'avoir guidé et conseillé au cours de ma formation d'anesthésiste-réanimateur.

A Monsieur le Docteur Guillaume Bouhours
Qui me fait l'honneur de juger ce travail,
Pour mon premier « déchocage » et ceux à venir,
Et pour le plaisir que j'ai eu à travailler et apprendre au bloc des urgences.

A Monsieur le Docteur Naren Schinkel
Qui est à l'origine de ce travail et me fait l'honneur de le juger,
Pour m'avoir guidé à toutes les différentes étapes de cette thèse,
Pour avoir lu, corrigé, approuvé ou repensé toutes les versions de cet article,
Pour Chicago, et notre collaboration, je le souhaite, sur de nouveaux travaux à venir,
Et parce que « CAPPRI, c'est (presque) fini ! »

A Madame le Docteur Aurélie Chaudet,

L' « O®tho, 2 ans pour tout changer… »,

Pour tous les EFOR qu'il reste à faire, tu verras ce sera super !

Pour les cafés, restos, barbecues… et pour continuer un peu plus à refaire le monde.

A mes collègues de promo et amis, Alexis le gars de la « Haute », Hélène – j'en trouve encore de tes objets perdus ! - , Mathieu - Simon a bien dormi ?-, Claire - des bisous ! -, Tarik - globalement…-, et tous les autres !

A mes chefs, Soizic, Carole, Damien, Stan… pour cette formation et pour les cafés.

Aux IADES et infirmières de réa et SSPI, Stéphanie, Clémence, Anne-Claire et les autres…

A mes amies de labo, Géraldine, Naïg, Céline… vous les faites quand mes Western-Blot ?

A mes amis, Souhil - Professeur -, Johann et Marie-Catherine - j'allais justement vous appeler-, Pierre -PP-, Matthieu - bientôt ton tour…

A ma famille,

A mes grands-parents,

A mes parents qui attendent ce moment depuis 11 années et même plus, qui y ont toujours cru et qui m'ont permis d'y croire jusqu'au bout. Cette thèse vous est dédiée.

A mes frères, soigneurs de plantes et d'animaux, moi aussi j'étais sûr que vous réussiriez !

A Anaïs et Corentin,

Pour chaque jour passé à vos côtés, tous plus merveilleux les uns que les autres…

LISTE DES ABREVIATIONS

ALR	Anesthésie loco-régionale
NS	Nerve stimulation
PACU	Post-anesthesia care unit
PNB	Peripheral nerve block
US	Ultrasound
VAS	Visual analogic scale

TABLE DES MATIERES

INTRODUCTION

L'anesthésie loco-régionale (ALR) occupe une place de plus en plus importante dans notre spécialité, dans des domaines variés que sont la chirurgie orthopédique et traumatique, adulte ou pédiatrique, l'obstétrique, mais aussi la chirurgie thoracique, abdominale, de la face et du cou et dans la prise en charge des douleurs chroniques. Deux évolutions majeures ont permis son développement dans le cadre de la réalisation des blocs nerveux périphériques : le passage du repérage des nerfs par paresthésie au repérage par neurostimulation, et depuis une dizaine d'années, l'utilisation de l'échographie.

L'échographie s'est en effet imposée récemment dans différents domaines de notre spécialité, pour l'évaluation de la fonction cardiaque ou des pathologies pulmonaires en réanimation, pour le repérage vasculaire avant la mise en place de cathéters veineux centraux ou artériels, pour l'évaluation rapide des lésions d'organes en traumatologie ("FAST échographie") et pour la réalisation des blocs nerveux périphériques, à visées anesthésique ou analgésique. Dans le cadre de l'ALR, l'échoguidage permet la visualisation directe des nerfs à bloquer, de l'injection d'anesthésique local au travers de l'aiguille et de la diffusion correcte au sein de la zone à bloquer. Elle permet en outre la visualisation de l'anatomie située en périphérie de manière à éviter une injection intra-vasculaire, intra-rachidienne, intra-pleurale ou intra-neurale et d'appréhender d'éventuelles variations anatomiques. Son utilisation en ALR a ainsi fait l'objet de nombreuses comparaisons avec l'utilisation, associée ou non, de la neurostimulation, et à montré la supériorité du guidage échographique pour augmenter le taux de réussite des blocs, diminuer les temps de réalisation et d'installation et augmenter la durée des blocs (1–3). Si elle permet par ailleurs une diminution de l'incidence des ponctions vasculaires accidentelles, son utilisation n'a cependant pas montré de bénéfice pour diminuer le nombre de complications neurologiques (paresthésies, déficits neurologiques prolongés) ni le nombre d'incidents liés à la toxicité des anesthésiques locaux (4), et nécessite donc un apprentissage rigoureux.

L'ALR échoguidée requiert en effet l'acquisition de connaissances et techniques particulières telles que la sonoanatomie, les principes de fonctionnement et l'utilisation d'un échographe, et une coordination entre la main tenant la sonde échographique, celle tenant l'aiguille et la visualisation sur l'écran de la zone à bloquer (5–7). Plusieurs études se sont intéressées à réaliser les courbes d'apprentissage des internes d'anesthésie pour la pratique de différentes techniques (mise en place d'une voie veineuse périphérique, intubation oro-trachéale, rachianesthésie et anesthésie péridurale) afin d'établir un nombre minimum d'actes à réaliser pour acquérir une compétence suffisante (8,9). Cependant, si de nombreuses études ont comparé ALR échoguidée et ALR utilisant la neurostimulation, peu d'études se sont intéressées à l'apprentissage de l'ALR échoguidée. Ces études utilisaient pour la majorité d'entre-elles des outils de simulation comme des pièces de viandes (10), des systèmes synthétiques « phantoms » (11,12) ou des cadavres (13). Pourtant, malgré le développement de la simulation dans notre spécialité et son apport démontré dans l'apprentissage des techniques médico-chirurgicales (12,14–16), l'apprentissage de l'ALR échoguidée reste le plus souvent réalisée au lit du patient, sur une durée courte lors du stage de trois à six mois dans le secteur de chirurgie orthopédique. Les recommandations françaises évaluent à 30 le nombre de blocs nécessaires par technique pendant l'apprentissage (17), mais dans une enquête française récente, 85% des internes d'anesthésie de dernière année déclaraient avoir réalisé moins de 30 blocs interscaléniques, 84% moins de 30 blocs sciatiques en sous-glutéal, 28% moins de 30 blocs fémoraux et 18% moins de 30 blocs axillaires (18). Ce nombre de 30 blocs nécessaires reposait principalement sur l'apprentissage de l'ALR utilisant la neurostimulation, et il est probable que l'apprentissage de l'ALR soit accelérée par l'utilisation de l'échoguidage, comme il l'a été observé pour le bloc axillaire (19) et que ce nombre dépende du type de bloc étudié.

L'objectif de ce travail était de réaliser les courbes d'apprentissages des internes d'anesthésie, au lit du patient pendant leur stage en chirurgie orthopédique, pour la réalisation sous échographie des quatre principaux blocs nerveux périphériques : le bloc interscalénique (pour la chirurgie de l'épaule et du coude), le bloc axillaire (pour la chirurgie de l'avant-bras et de la main), le bloc fémoral (pour la chirurgie du genou principalement) et le bloc sciatique (pour la chirurgie de la jambe et du pied). Deux types de courbes ont été réalisées, celles évaluant la réussite du bloc, c'est à dire permettant la chirurgie et l'analgésie, et celles évaluant le temps d'exécution des blocs. Le temps d'exécution a en effet son importance en ALR puisqu'il retentit potentiellement sur la tolérance du patient lors du geste, la fatigue ou l'énervement de celui qui exécute le geste, et sur la gestion du programme opératoire. Ce temps d'éxécution a été comparé avec celui de deux anesthésistes expérimentés, les complications ont été relevées et les erreurs gestuelles effectuées par les internes ont été analysées.

Ce travail, dont j'avais pu présenter les premiers résultats au congrès de l'American Society of Anesthesiology à Chicago en 2011 à la session poster « Regional anesthesia and acute pain » et au « Resident Research Forum » (annexe 1), est présenté dans cette thèse sous la forme d'un article original à soumettre.

ARTICLE ORIGINAL

Learning curves of main peripheral nerve blocks using ultrasound guidance : how many blocks are necessary in a context of care ?

Abstract

Introduction

Learning of ultrasound–guided regional anesthesia differs from learning of regional anesthesia using nerve stimulation (NS). Simulation devices are usally used to establish learning curves of regional anesthesia using ultrasound (US). The aim of our study was to determine for the main peripheral nerve blocks, the attempts' number required by inexperienced anesthesiology residents in a context of care to acquire competency in regional anesthesia using US.

Methods

In a prospective observational study, 8 inexperienced residents were included, each for a period of 3 months. All pre-operative interscalene, axillary, femoral and sciatic blocks were chronologically included and performed using US guidance and NS in sentinel mode. Two types of learning curves were constructed : learning curves assessing block efficiency and learning curves assessing execution times of blocks performed by residents (rates of efficient blocks with an execution time equal or less than the 75th percentil of that of 2 anesthesiologists with expertise in regional anesthesia using US). These curves were assessed for each block type and for all block types taken together during learning. Finally, the execution time of each block type was compared with that of experts and errors distribution during learning was studied.

Results

522 blocks from the 8 residents were included (192, 66, 150, 114 respectively for interscalene, axillary, femoral and sciatic blocks). 91% of blocks were efficient in the study and more than 80% at the beginning of the learning. On the criterion of execution time, success rates were greater than 80% after 25 blocks for interscalene and femoral blocks and after 20 blocks for sciatic block. However, all block types taken together in chronological order of execution, success rate on this criterion of execution time was greater than 80 % only after 80 blocks performed. There was a significant reduction in execution time between blocks 1-5 and 6-10 for interscalene, axillary and femoral blocks and between blocks 1-5 and 11-15 for sciatic block. There was no significant difference between experts and residents execution times after the 15th attempt of each block type. Poor visualization of the needle tip was the most frequent error (26% of blocks) and persisted until the end of the course with a significant association with failed blocks ($p < 0.0001$).

Conclusion

Learning of regional anesthesia using US by previously inexperienced anesthesiology appears to be easy, with more than 90% of the blocks efficient. A number between 20 and 25 blocks of each type is probably required to acquire comparable performance to those of experts in terms of block efficiency and execution time.

Keywords

Learning curves

Regional anesthesia

Ultrasound

Residents

Context of care

Introduction

Since the past 50 years, regional anesthesia has become an usual and safe technique of anesthesia. Among all peripheral nerve block (PNB) techniques, nerve stimulation (NS) is or used to be the gold standard. Indeed, recently ultrasonography (US) has become a standard of practice for PNB. Learning of US guided regional anesthesia is thus of great interest, but it differs from learning of regional anesthesia using NS. This technique requires special skills such as knowledge of US anatomy, handling of the device, coordination between needle insertion and placement of the probe (20).

Several studies have attempted to establish the learning curves of various anesthetic procedures (8,9) : peripheral venous catheter insertion, orotracheal intubation, spinal and epidural anesthesia. These studies have shown that a sufficient expertise was obtained with a few numbers of acts. In the case of regional anesthesia using US, few studies have focused on learning curves for inexperienced anesthesiology residents. Most of these studies used simulation devices with experimental models such as pieces of meat or gels (10–12). In a context of care, Sites and al. characterized the novice (anesthesiology residents) behavior associated with learning of US guided PNB and reported a rapid decrease of errors during the learning of different block types taken together (20). However they did not compare novices' performance to experts' ones. They highlighted two major mistakes : poor visualization of the needle tip and involuntary movements of the probe (20). Another study has compared retrospectively the learning curves for axillary brachial plexus block using US or NS (19), and reported a faster learning with US with regard to success rate. Authors concluded that residents need a close supervision for at least the first

15 axillary blocks. A same number of 15 blocks was found in a previous study evaluating senior anesthesiologists learning US axillary block (21).

However, these studies did not evaluate the learning of the main peripheral nerve blocks using US in a context of care. Moreover, they did not compare block execution times with those of expert anesthesiologists in US guided regional anesthesia. Our aim was to assess the minimum number of blocks required for unexperiment anesthesiology resident to acquire sufficient profiency for US guidance of each of the following PNB: interscalene, axillary, femoral and sciatic blocks.

Materials and methods

Enrollment

After ethics committee approval, the study was conducted from May 2009 to May 2011 in the Orthopedic Surgery Unit of our Anaesthesiology Department in the University Hospital of Angers, France. It is the French practice to have learning residents in charge of patient care, and patients are aware of it, no specific consent was thus required from patients according to our local ethic committee.

Our residents in anesthesiology have to practice in the different sectors of the anesthesiology department, and move every 3 months from one to another surgical sector. Residents were proposed to join the study during their period in the orthopedic surgery unit, only if they had an experience of less than 5 US-guided blocks of any kind.

Study design

Each resident was included for a three months period (normal duration of their rotation in orthopedic surgery). Documents explaining the US device main functions, appearances of nerves involved in the study and principles of regional anesthesia using US were provided to the residents in the month preceding their period in the orthopedic unit (22; annexes 2,3). Residents who agreed to participate received a questionnaire to precise their age, gender, handedness, postgraduate semester, experience in regional anesthesia using US or NS, experience in other techniques using US and on their experience in video games (annexe 4).

All type of blocks (i.e.: interscalene, axillary, femoral and sciatic blocks) performed in the preoperative period were included in a chronological order. These blocks were performed using a LOGIQ ultrasound device (General Electric Healthcare, Fairfield, USA), a Stimuplex® HNS 12 nerve stimulator and Stimuplex® needles (B. Braun, Melsungen, Germany). NS was used in sentinel mode with low intensity (0.5 mA), a frequency of 2 Hz and a duration of 100 ms. A motor response was not systematically sought and it was possible to inject the local anesthetic using US guidance alone. All blocks were performed with in-plane visualization of the needle. Interscalene, axillary and femoral blocks were performed with 50 mm needle and sciatic blocks with 100 mm needles and diameters between 19 and 22 Gauge. Single shot block or perineural catheter placement were evaluated. Local anesthetic solutions were ropivacaine, levobupivacaine, lidocaine with or without epinephrine, or equimolar mixtures of these solutions, depending on the type of block and surgical procedures. Volume of solution could not exceed 40 mL.

The puncture sites were those usually described in the literature (23–25). Interscalene block was performed in the supine position, with an approximately 30° rotation of the patient head on the side opposite to the puncture. Puncture was performed at the inner edge of the probe in an anteroposterior direction. A 30 mL injection of local anesthetic solution was carried out to obtain a good distribution around the nerves. Axillary block was performed in the supine position with the arm abducted to 90 ° and hand suppination. The puncture was performed in the axilla at the lateral edge of the probe. The median, radial, ulnar and musculocutaneous nerves were blocked individually by injecting 5 to 10 mL of local anesthetic. The femoral block was performed in the supine position. The puncture was performed at the lateral edge of the probe. A 20 mL injection of local anesthetic was performed. The sciatic block was performed by posterior approach in prone position. Puncture was performed upstream of the sciatic nerve division to allow intraoperative use of a tourniquet, at the lateral edge of the probe. A 30 mL injection of local anesthetic was carried out to obtain an image of a sciatic nerve completely surrounded by the solution. Residents were supervised by one of the three experienced anesthetists working in the orthopedic unit.

Peripheral nerve blocks evaluation

For each block, the following parameters were recorded by the nurse or the experienced anesthetist assisting the resident : execution time from insertion of the needle to the end of the injection, preparation time (material preparation and nerve ultrasound locating), numbers of skin punctures and skin replacements, volume of injection, occurrence of complication, sensory and motor block at 10, 20 and 30 minutes (annexe 5). If a catheter was introduced, the execution time did not include the introduction of the catheter, but only the time between the puncture until the end of the injection with the needle.

During the realization of blocks, errors were recorded as described by Sites et al in their study (20). The expert anesthesiologist had to identify errors among a predefined list : non visualization of the needle tip during advancement, unintentional mobilization, mistakes in identification of anatomical structures, wrong recognition of the image side, incorrect setting of the US device, inadequate equipment preparation, neural target malposition on the screen, excessive visual focus on hands instead of the screen, poor visualization of local anesthetic drug distribution, fatigue onset in resident, malposition of the back, position with turned head, use of the needle with the non-dominant hand, and a number of skin punctures or skin replacements greater than two. A score of errors (ranging from 0 to 15) was calculated, each of these items valuate one point.

In the post-anesthesia care unit (PACU), nurses collected patients' pain using a visual analogic scale (VAS) and patients' satisfaction of their management under regional anesthesia using a numeric scale : 0 (not satisfied at all) to 10 (completely satisfied). Nurses also collected amount of intravenous morphine used in the PACU. Patient follow-up ended at release from PACU.

In order to compare residents and experts performances, the execution times for completion of these 4 blocks by two anesthesiologist experts were measured.

Outcome measurements

Two types of learning curves were constructed. First, learning curves evaluating the efficiency of blocks performed by residents was built. A block was not considered efficient in case of: need for unplanned general anesthesia, need for an additional PNB, assistance of the anesthetist supervisor for the realization of the PNB and in absence of sensory block 20 minutes after completion. The percentage of efficient blocks was calculated for each set of 5 consecutive blocks for all residents to construct the curve. As the number of efficient blocks is high using US guidance, learning curves evaluating execution times of blocks performed by residents were also built. For this, we mesured the percentage of efficient blocks with an execution time equal or less than the 75^{th} percentile of the experts' time for each set of 5 consecutive blocks performed by all residents.

Our secondary objective was to compare residents' execution times of each block type with experts' execution times to determine the number of blocks required by residents to gain an efficiency close to the experts' one. Residents execution times were compared for each set of 5 consecutive blocks (all residents included) with experts execution times and with the first set of 5 consecutive blocks. Finally, we measured the number of complications, errors and distribution of these errors during learning.

Statistical analysis

Results are reported as number (%), mean ± SD or median [Q1-Q3] as appropriate. Numerical data were compared using Mann-Whitney test. Statistical analyses were performed with SPSS 13.0® (SPSS Inc., Chicago, IL). Two-sided P values < 0.05 were considered significant.

Results

Eight residents participated to the study. Residents' demographic data are shown on table 1. We evaluated 616 blocks. Among them, 522 performed by the 8 residents (192, 66, 150, 114 for interscalene, axillary, femoral and sciatic blocks respectively) and 94 performed by the 2 experts (31, 9, 18, 36 for interscalene, axillary, femoral and sciatic blocks respectively). Blocks characteristics performed by residents are shown on table 2.

Table 1. Resident's demographic data.

	Residents (n = 8)
Age mean	29.6 ± 1.8
Gender (F : M)	4 : 4
Handedness (R : L)	6 : 2
Postgraduate semester	
6	5
7	2
9	1
RA experience	
Using NS	
0 - 20 blocks	5
50 - 70 blocks	1
70 - 100 blocks	2
With ultrasound guidance	
0 - 5 blocks	6
Ultrasound experience	7
Cardiac US	7
Pleural US	3
Central venous line	1
Video game player	
Active player	3
Past 5 years player	2

Abbreviations : F, female; M, male; R, right-handed; L, left-handed; RA, regional anesthesia; NS, nerve stimulator; US, ultrasound

Table 2. Characteristics of the 4 peripheral nerve blocks performed by the residents

	Interscalene block n = 192	Axillary block n = 66	Femoral block n = 150	Sciatic block n = 114
Site of surgery				
Shoulder	190 (99%)	-	-	-
Elbow	1 (1%)	8 (12%)	-	-
Hand and wrist	-	58 (88%)	-	-
Knee	-	-	111 (74%)	2 (2%)
Femur	-	-	1 (1%)	-
Leg	-	-	-	1 (1%)
Foot and ankle	-	-	38 (25%)	111 (97%)
Catheter placement	155 (81%)	0	103 (69%)	83 (73%)
Sedation	113 (59%)	28 (42%)	55 (37%)	74 (65%)
Volume of LA used (mL)	22.8 ± 5.2	25.9 ± 4.6	22.0 ±5.9	24.6 ± 6.1
No use of nerve stimulation	51 (27%)	8 (12%)	23 (15%)	17 (15%)
Failures	3 (2%)	11 (17%)	9 (6%)	14 (12%)
Preparation time (min)	5.3 ± 3.4	3.8 ± 2.0	5.3 ± 2.4	6.3 ± 4.0
Execution time (min)	5.1 ± 4.3	8.6 ± 4.6	3.8 ± 3.0	5.9 ± 4.1
Complications	6 (3%)	0	0	0
Air injection	1	-	-	-
Intravascular catheter	1	-	-	-
Vascular puncture	2	-	-	-
Vasovagal syncope	2	-	-	-
Patient satisfaction in PACU (0-10)	8.7 ± 1.7	8.6 ± 1.9	8.6 ± 1.9	9.0 ± 1.4
Pain (VAS) in PACU	1.4 ± 2.4	0.8 ± 2.3	2.0 ± 3.0	1.1 ± 2.1
Morphine consumption in PACU (mg)	0.7 ± 2.2	0.0 ± 0.2	1.9 ± 3.8	0.9 ± 2.2

Values are means ± standard deviations, numbers and percents. Abbreviations : LA, local anesthetic; mL, milliliter; PACU, post-anesthesia care unit; VAS, visual analogue scale.

Block efficiency

91% of blocks performed by residents were efficient. Failure rates were more important for axillary (17%, p = 0.016) and sciatic (12%, p = 0.02) blocks as shown in table 2. Non efficient blocks were represented by the need of an additional PNB in 14 (39%) patients, unplanned general anesthesia in 15 (47%), or supervisor assistance in 7 (19%) patients. Efficient blocks rates across time of learning are shown in figure 1 for the different block types and for all block types taken together. Efficient blocks rates were greater than 80% at the beginning of learning for all block types, except for sciatic block with a 72% success rate for blocks 6-10. Success rates were above 95% (and equal to 100%) after only 10 blocks for interscalene block, and 25 blocks for femoral and sciatic blocks. Residents did not performed more than 15 axillary blocks during the 3-month period, with a final success rate of 91%. Considering all block types taken together, success rate remained higher than 95% only after 80 blocks performed.

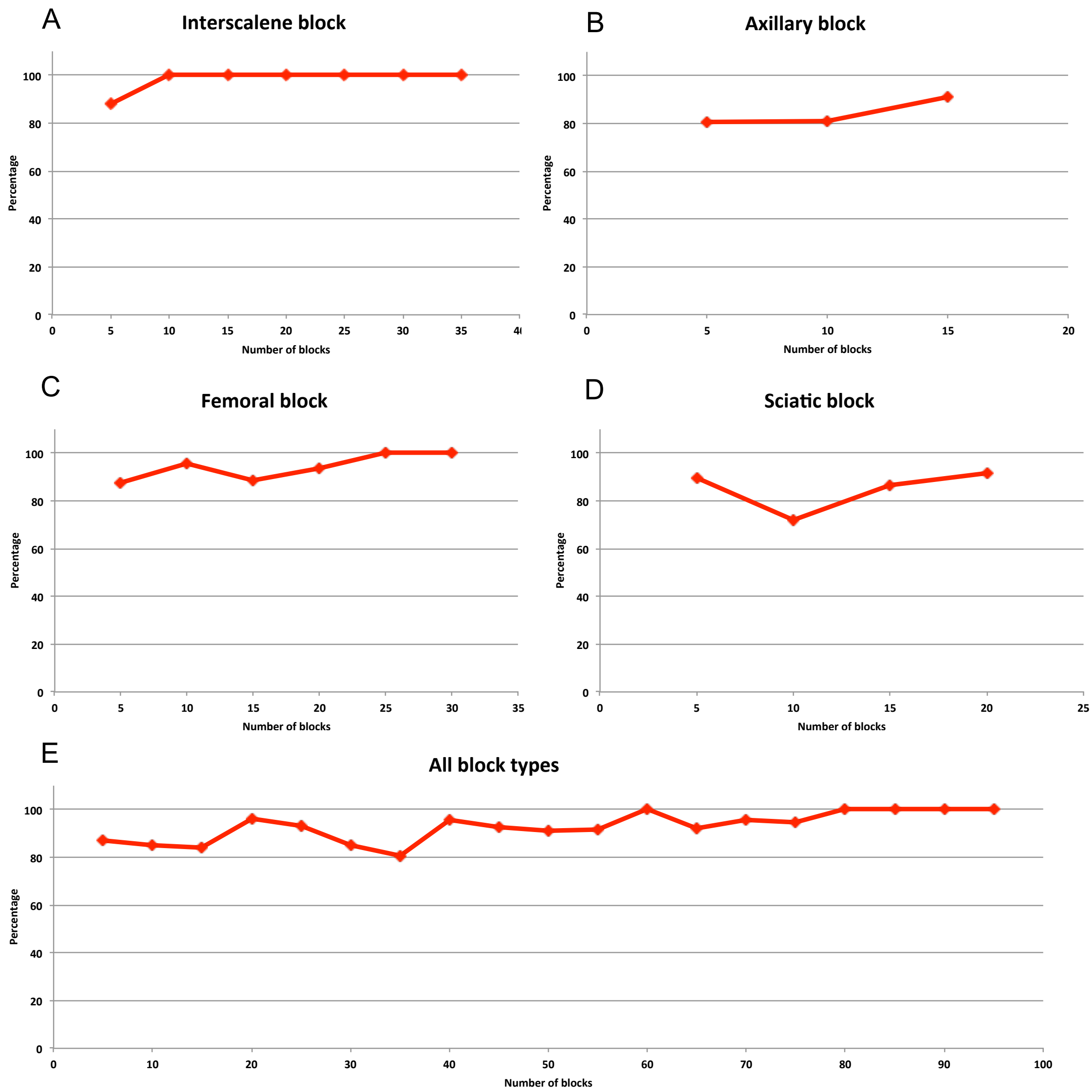


Figure 1. Learning curves assessing block efficiency : percentages of efficient blocks (by groups of 5 consecutive blocks) performed by residents in chronological order of completion. A : interscalene block, B : axillary block, C : femoral block, D : sciatic block, E : all block types.

Execution times

Figure 2 shows the percentage of efficient blocks with an execution time ≤ 75th percentile of experts' time. For the 5 first blocks performed, this rate was lower than 30% for interscalene, axillary and femoral blocks and equal to 35% for sciatic block. It became greater than 80% after 25 blocks performed for interscalene and femoral blocks and after 20 blocks for sciatic block. Success rates on this criterion could not be evaluated after 15 blocks for axillary block and was only 55% at the end of the 3 months for this block. Considering all block types together in order of execution, success rate was greater or equal to 80% only after 80 blocks performed.

Figure 3 shows the median execution times of each block type for the experts (3 [2-5] min for interscalene block, 6 [5.2-6.3] min for axillary block, 2 [2-3] min for femoral block and 3.15 [2.8-5] min for sciatic block) and for the resident by sets of 5 consecutive blocks. After the 15th block performed, there was no significant difference between experts and residents times for each of the 4 block types (4 [3-5] min, p = 0,667 for interscalene block, 6 [5-10] min, p = 0,34 for axillary block, 3 [2-3] min, p = 0,567 for femoral block, 4 [2-8] min, p = 0,75 for sciatic block).

Residents were even more rapid than experts for femoral block after the 25th blocks performed with a median time of 1[1-2] min vs 2[2-3] (p = 0.004). For axillary block, the median time was not different from that of experts once 10 blocks performed but this time corresponded to those of 5 residents only, others having not performed more than 5 axillary blocks during their rotation, and was compared with only nine expert blocks. Finally, there was a significant reduction in execution time between blocks 1-5 and 6-10 for interscalene (p <0.0001), axillary (p = 0.0025) and femoral (p = 0.02) blocks. For sciatic block, this decrease was significant only from blocks 11-15 compared to the first five blocks (p = 0.002).

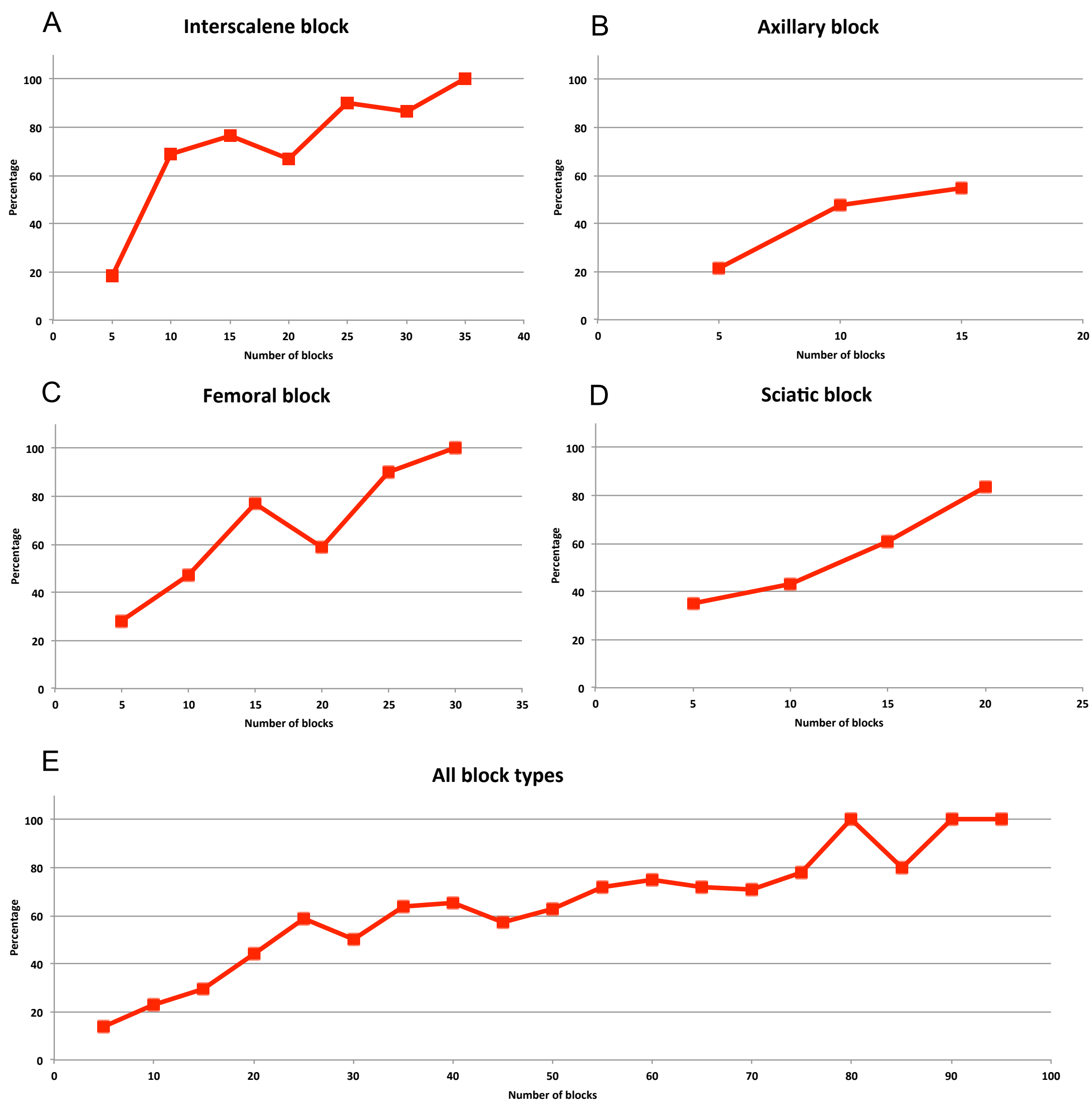


Figure 2. Learning curves assessing block execution times : percentages of efficient blocks with an execution time equal or less than the 75th percentil of that of experts in chronological order of completion by residents (by groups of 5 blocks). Experts' median times needed for each block are given in (): A : interscalene block (5 min), B : axillary block (6.3 min), C : femoral block (3min), D : sciatic block (5min), E : all block types.

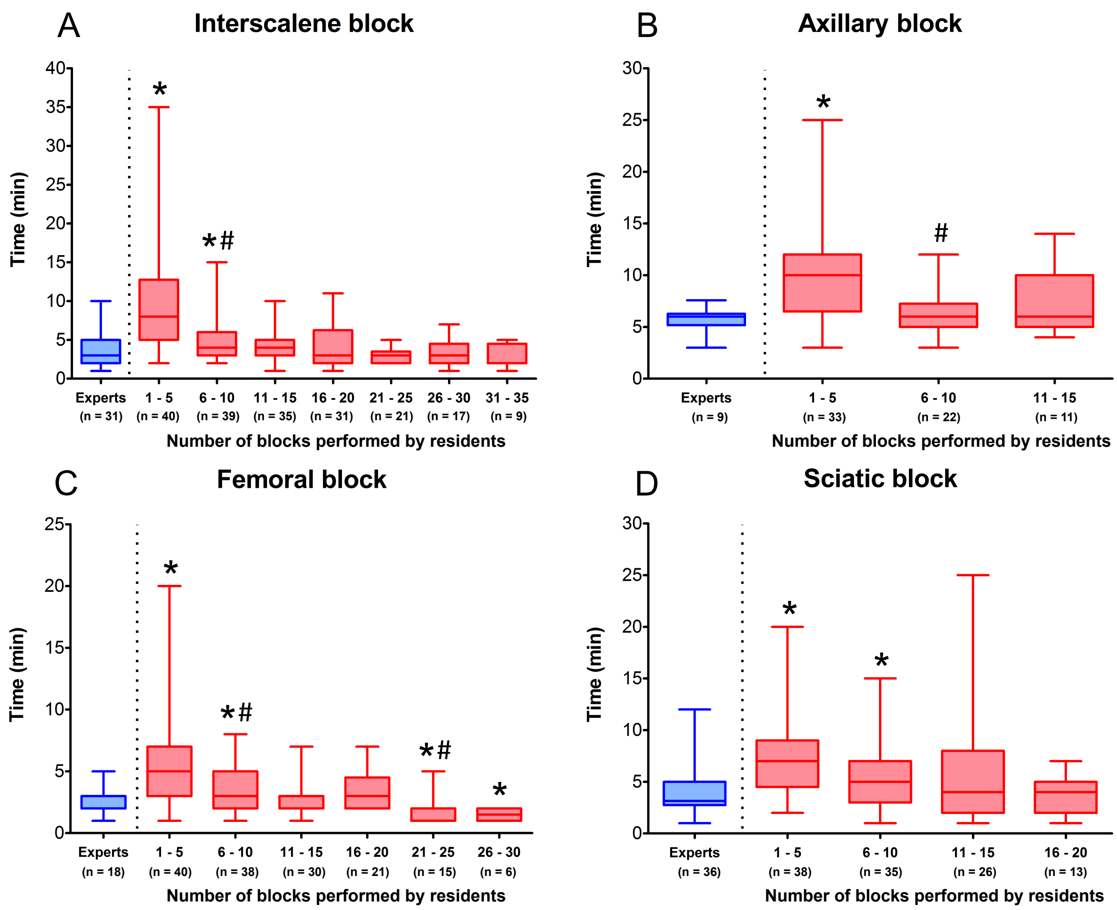


Figure 3. Execution times of each type of block (A : interscalene block, B : axillary block, C : femoral block, D : sciatic block) for residents in chronological order of completion (by groups of 5 blocks) and for experts. * : p < 0.05 compared with experts. # : p < 0.05 compared with the previous group of 5 blocks performed by residents.

Errors

The mean error score was 0.8 ± 1.2 (median score 1 [0-1]), 1.7 ± 1.7 (1 [0-3]) before 20 blocks against 0.5 ± 0.8 (0 [0-1]) after 20 blocks (p <0.0001). It was significantly higher for sciatic (1.3 ± 1.3) and axillary (1.0 ± 1.5) blocks in comparison with interscalene (0.7 ± 1.2) or femoral (0.6 ± 0.9) blocks (p<0.05).

Different errors are depicted in table 3. The three most frequent errors were poor visualization of the needle tip in 129 (26 %) cases, poor recognition of the anatomy in 58

(12 %) cases and involuntary mobilization of the probe in 44 (9 %) cases. Poor visualization of the needle tip was the most frequently encountered error all along the learning and persisted until the end of the 3 months. The type of errors significantly associated with failed blocks compared to successful ones were : non visualization of the needle tip during advancement (40% vs 17%, $p < 0.0001$), neural target malposition on the screen (8% vs 2%, $p = 0.001$), unintentional mobilization (14% vs 4%, $p = 0.0003$), mistakes in identification of anatomical structures (19% vs 6%, $p < 0.0001$), use of non-dominant hand (5% vs 1%, $p = 0.02$), a number of skin punctures ≥ 2 (9% vs 0.4%, $p < 0.0001$) and a number of skin replacements ≥ 2 (12% vs 2%, $p = 0.0001$).

Complications

Six complications were observed with the interscalene block : an injection of air, an intravascular catheter, two vascular punctures and two vagal malaise. None of them were responsible for serious consequences.

Table 3. Chronological distribution of errors commited by residents

	Blocks 1-10 (n = 73)	Blocks 11-20 (n = 73)	Blocks 21-30 (n = 72)	Blocks 31-40 (n = 70)	Blocks 41-50 (n = 66)	Blocks 51-60 (n = 60)	Blocks 61-70 (n = 54)	Blocks 71-80 (n = 28)
Skin punctures > 2	4 (5%)	7 (10%)	3 (4%)	2 (3%)	1 (2%)	2 (3%)	1 (2%)	0 (0%)
Skin returns > 2	10 (14%)	10 (14%)	1 (1%)	1 (1%)	3 (5%)	1 (2%)	2 (4%)	1 (4%)
Bad recognition of the side	4 (5%)	2 (3%)	2 (3%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)
Non visualization of the needle tip	36 (49%)	26 (36%)	17 (24%)	15 (21%)	12 (18%)	6 (10%)	12 (22%)	5 (17%)
Unintentional mobilization	16 (22%)	21 (29%)	4 (6%)	1 (1%)	1 (2%)	1 (2%)	0 (0%)	0 (0%)
Mistake in anatomical identification	19 (26%)	14 (19%)	5 (7%)	2 (3%)	3 (5%)	7 (12%)	5 (9%)	1 (4%)
Incorrect setting of the device	5 (7%)	3 (4%)	3 (4%)	0 (0%)	2 (3%)	0 (0%)	0 (0%)	1 (4%)
Inadequate equipment preparation	6 (8%)	6 (8%)	1 (1%)	1 (1%)	2 (3%)	0 (0%)	0 (0%)	0 (0%)
Malposition on the screen	9 (12%)	5 (7%)	0 (0%)	4 (6%)	5 (8%)	0 (0%)	0 (0%)	0 (0%)
Excessive visual focus on hands	4 (5%)	1 (1%)	2 (3%)	3 (4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Malposition of the back	10 (14%)	6 (8%)	2 (3%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)	2 (7%)
Head turned	6 (8%)	3 (4%)	1 (1%)	2 (3%)	2 (3%)	1 (2%)	4 (7%)	3 (11%)
Needle in the non-dominant hand	6 (8%)	4 (5%)	1 (1%)	3 (4%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)
Poor visualization of LA distribution	3 (4%)	1 (1%)	0 (0%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)
Resident fatigue onset	3 (4%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Discussion

We observe that more than 80 % of the five first blocks performed by inexperienced residents are efficient using US guidance. In addition, after having performed 25 interscalene and femoral blocks and 20 sciatic blocks, resident performances equaled experts' ones with regard to execution time. As different types of blocks are performed according to the hazard of the surgical shedule, 80 blocks of all types are needed during the learning to achieve this performance. We identify the most frequent errors that are associated with decrease performance.

Despite the development of simulation and specific course on regional anesthesia, learning of regional anesthesia by anesthesiology residents is often performed at the bedside, and may thus interfere with the routine of a busy anesthetic service. Besides, concerning learning of regional anesthesia using nerve stimulation, the European Board of Anaesthesiology and the French Society of Anesthesiology and Intensive Care recommend having performed between 10 to 60 blocks to be considered efficient, depending on type of blocks (17,26). As a matter of fact, we report high rates of success and little waste of time in our study during learning of regional anesthesia using US guidance. Indeed, the use of US guidance has shown its superiority over NS to increase success rates and reduce execution times of peripheral nerve blocks (1,2). In the context of learning by inexperienced residents, Sites et al. confirms rapid learning of regional anesthesia using US, with a rapid decrease in execution times and errors (20) and in a retrospective study using a database, Orebaugh et al. showed shorter times, higher success rates and reduced number of vascular punctures and needle repositioning with the use of US (27). As a result, the number of needed blocks proposed for regional anesthesia using NS probably differs from the number required using US guidance. For the axillary block, recent studies using US guidance confirmed that a number of only 15 blocks is probably sufficient during learning, whether by residents or by anesthesiologists with expertise in NS (19,21). However, this number probably depends on the type of block and the criteria considered.

We first evaluated the percentage of efficient blocks of each type performed by residents. 91 % of blocks were efficient in our study and more than 80 % at the beginning of the learning. These results are consistent with those obtained in studies using US guidance. For interscalene block, studies found success rates of 95.9% (20) and 97.3% (28) for inexperienced residents, without difference between junior and senior residents, although Kapral et al. found 99% (29) and Liu et al 100% (30) for physicians. For axillary block, a 83.3 % success rate was found for inexperienced resident and between 80 and 97% for experienced anesthesiologists (31–33). For femoral block, 95.1 and 82.3 % success rates were found for single shot and continuous femoral blocks respectively for inexperienced residents (20). For the sciatic block with posterior approach, a 93.6 % success rate was found for experienced anesthesiologists (34). For all types of blocks, Sites and al. and Orebaugh and al. found respectively overall success rates of 93.6% and 97% for inexperienced residents. In our study, a rate of efficient PNB above 95% was obtained after 80 blocks.

In addition to the efficiency of the PNB, we looked for the execution time. Success rates, defined as an efficient block with an execution time $\leq 75^{th}$ of experts, were above 80% after 25 interscalene or femoral blocks and 20 sciatic blocks. While this time criterion is quite strict (only 1 min longer than the expert median time for axillary and femoral blocks and 2 min longer for interscalene and sciatic blocks), we observed that learning of each block type is fast using US guidance. Indeed, execution time significantly decreased from the beginning of learning between blocks 1-5 and 6-10 for interscalene axillary and femoral blocks. For sciatic block, learning seems more progressive as time did not decrease significantly between blocks 1-5 and 6-10, but only after blocks 11-15. This is probably due to the difficulty to visualize the sciatic nerve by a posterior approach. Times obtained in our study for experts and residents after learning, are consistent with those reported in the literature with the use of US guidance. For interscalene block, Orebaugh et al. (27) found a median time of 1[0.8-1.8] min for residents but this study did not assess the time of local anesthetic mixture injection. For experts, Liu et al. (30) observed a mean time of 5 min. For the axillary block, data are discordant with duration between 6.7±1.3 and 12.4±4.8 min (33,35) for experts and 10.5 [7.7-12.5] min for residents (27). For the femoral block, a median time of 1.5 [0.6-2.9] min was found for residents (27). For the sciatic block, 6.0 ± 3.0 min were measured for experienced anesthesiologists (36). Thus, a number of attempts between 20 and 25 seems sufficient to acquire complete competency in regional anesthesia including execution time.

Finally, our study shows a rapid decrease of all type of errors during learning. Non visualization of the needle tip during advancement, neural target malposition on the screen, unintentional mobilization, mistakes in identification of anatomical structures and use of non-dominant hand were associated with poor success rates in terms of efficiency and execution times. Needle progression without extremity visualization is the most common error, as already reported (20), and persists during the learning for almost 20% of blocks. This error must then be a specific objective for teaching because of the potentially risks of nerve or vascular punctures.

Some limitations in this study must be specified. We only included 8 residents and we were not able to evaluate the impact of previous competence on US and/or NS on learning curves. However, this number is consistent with previous studies on PNB learning (19,20,27) and the number of blocks studied is important. We did not measure the time prior to needle insertion (i.e. preparation of the material, ultrasound nerve identification and localization…). This time may be prolonged when nerves are not easily visualized (poor echogenicity, obesity, anatomical variations…). However, execution time measured in our study included part of the identification of the nerves and the correction time of the targets based on needle visualization and responses obtained with neurostimulation. Besides, we couldn't conclude for the minimum number of axillary blocks to be performed because residents performed less than 15 each during their 3-months rotation.

Conclusion

Learning of PNB under US by previously inexperienced anesthesiology appears to be easy, with more than 90% of the blocks efficient. Moreover, resident performance appears to be close to experts' ones after 20 to 25 blocks of each type.

REFERENCES

1. Abrahams MS, Aziz MF, Fu RF, Horn J-L. Ultrasound guidance compared with electrical neurostimulation for peripheral nerve block: a systematic review and meta-analysis of randomized controlled trials. Br J Anaesth. mars 2009;102(3):408-417.
2. Gelfand HJ, Ouanes J-PP, Lesley MR, Ko PS, Murphy JD, Sumida SM, et al. Analgesic efficacy of ultrasound-guided regional anesthesia: a meta-analysis. J Clin Anesth. mars 2011;23(2):90-96.
3. Schnabel A, Meyer-Frießem CH, Zahn PK, Pogatzki-Zahn EM. Ultrasound compared with nerve stimulation guidance for peripheral nerve catheter placement: a meta-analysis of randomized controlled trials. Br J Anaesth. 5 juin 2013;aet196.
4. Barrington MJ, Watts SA, Gledhill SR, Thomas RD, Said SA, Snyder GL, et al. Preliminary results of the Australasian Regional Anaesthesia Collaboration: a prospective audit of more than 7000 peripheral nerve and plexus blocks for neurologic and other complications. Reg Anesth Pain Med. déc 2009;34(6):534-541.
5. Bouaziz H, Aubrun F, Belbachir A, Cuvillon P, Eisenberg E, Jochum D, et al. Ultrasound-guided regional anesthesia. Ann Fr Anesth Reanim. sept 2013;32(9):e119-120.
6. Sites BD, Chan VW, Neal JM, Weller R, Grau T, Koscielniak-Nielsen ZJ, et al. The American Society of Regional Anesthesia and Pain Medicine and the European Society of Regional Anaesthesia and Pain Therapy joint committee recommendations for education and training in ultrasound-guided regional anesthesia. Reg Anesth Pain Med. avr 2010;35(2 Suppl):S74-80.
7. Smith HM, Kopp SL, Johnson RL, Long TR, Cerhan JH, Hebl JR. Looking into learning: visuospatial and psychomotor predictors of ultrasound-guided procedural performance. Reg Anesth Pain Med. août 2012;37(4):441-447.
8. Konrad C, Schüpfer G, Wietlisbach M, Gerber H. Learning manual skills in

anesthesiology: Is there a recommended number of cases for anesthetic procedures? Anesth Analg. mars 1998;86(3):635-639.

9. De Oliveira Filho GR. The construction of learning curves for basic skills in anesthetic procedures: an application for the cumulative sum method. Anesth Analg. août 2002;95(2):411-416, table of contents.

10. Sites BD, Gallagher JD, Cravero J, Lundberg J, Blike G. The learning curve associated with a simulated ultrasound-guided interventional task by inexperienced anesthesia residents. Reg Anesth Pain Med. déc 2004;29(6):544-548.

11. Dessieux T, Estebe J-P, Bloc S, Mercadal L, Ecoffey C. [Evaluation of the learning curve of residents in localizing a phantom target with ultrasonography]. Ann Fr Anesth Reanim. oct 2008;27(10):797-801.

12. Niazi AU, Haldipur N, Prasad AG, Chan VW. Ultrasound-guided regional anesthesia performance in the early learning period: effect of simulation training. Reg Anesth Pain Med. févr 2012;37(1):51-54.

13. Kessler J, Moriggl B, Grau T. Ultrasound-guided regional anesthesia: learning with an optimized cadaver model. Surg Radiol Anat. 25 août 2013;

14. Issenberg SB, McGaghie WC, Hart IR, Mayer JW, Felner JM, Petrusa ER, et al. Simulation technology for health care professional skills training and assessment. JAMA. 1 sept 1999;282(9):861-866.

15. Seymour NE, Gallagher AG, Roman SA, O'Brien MK, Bansal VK, Andersen DK, et al. Virtual reality training improves operating room performance: results of a randomized, double-blinded study. Ann Surg. oct 2002;236(4):458-463; discussion 463-464.

16. Granry J-C, Moll M-C. Haute Autorité de Santé - Rapport de mission : Etat de l'art (national et international en matière de pratiques de simulation dans le domaine de la santé. Dans le cadre du développement professionnel continu (DPC) et de la prévention des

risques associés aux soins. 2012; Disponible sur: http://www.has-sante.fr/portail/upload/docs/application/pdf/2012-01/simulation_en_sante_-_rapport.pdf

17. Ripart J. [What training for locoregional anesthesia?]. Ann Fr Anesth Reanim. janv 2006;25(1):89-95.

18. Laigle C, Bart F, Dupont H. [Initial training in regional anesthesia for the French residents: a nationwide survey]. Ann Fr Anesth Reanim. sept 2012;31(9):687-693.

19. Luyet C, Schüpfer G, Wipfli M, Greif R, Luginbühl M, Eichenberger U. Different Learning Curves for Axillary Brachial Plexus Block: Ultrasound Guidance versus Nerve Stimulation. Anesthesiol Res Pract. 2010;2010:309462.

20. Sites BD, Spence BC, Gallagher JD, Wiley CW, Bertrand ML, Blike GT. Characterizing novice behavior associated with learning ultrasound-guided peripheral regional anesthesia. Reg Anesth Pain Med. avr 2007;32(2):107-115.

21. Morros C, Pérez-Cuenca MD, Sala-Blanch X, Cedó F. [Ultrasound-guided axillary brachial plexus block: learning curve and results]. Rev Esp Anestesiol Reanim. févr 2011;58(2):74-79.

22. Chin KJ, Perlas A, Chan VWS, Brull R. Needle visualization in ultrasound-guided regional anesthesia: challenges and solutions. Reg Anesth Pain Med. déc 2008;33(6):532-544.

23. Delaunay L, Plantet F, Jochum D. [Ultrasound and regional anaesthesia]. Ann Fr Anesth Reanim. févr 2009;28(2):140-160.

24. Chan VWS, Perlas A, Rawson R, Odukoya O. Ultrasound-guided supraclavicular brachial plexus block. Anesth Analg. nov 2003;97(5):1514-1517.

25. Chan VWS, Nova H, Abbas S, McCartney CJL, Perlas A, Xu DQ. Ultrasound examination and localization of the sciatic nerve: a volunteer study. Anesthesiology. févr 2006;104(2):309-314, discussion 5A.

26. Training guidelines in anaesthesia of the European Board of Anaesthesiology

Reanimation and Intensive Care. Eur J Anaesthesiol. sept 2001;18(9):563-571.

27. Orebaugh SL, Williams BA, Kentor ML. Ultrasound guidance with nerve stimulation reduces the time necessary for resident peripheral nerve blockade. Reg Anesth Pain Med. oct 2007;32(5):448-454.

28. Orebaugh SL, Williams BA, Kentor ML, Bolland MA, Mosier SK, Nowak TP. Interscalene block using ultrasound guidance: impact of experience on resident performance. Acta Anaesthesiol Scand. nov 2009;53(10):1268-1274.

29. Kapral S, Greher M, Huber G, Willschke H, Kettner S, Kdolsky R, et al. Ultrasonographic guidance improves the success rate of interscalene brachial plexus blockade. Reg Anesth Pain Med. juin 2008;33(3):253-258.

30. Liu SS, Zayas VM, Gordon MA, Beathe JC, Maalouf DB, Paroli L, et al. A prospective, randomized, controlled trial comparing ultrasound versus nerve stimulator guidance for interscalene block for ambulatory shoulder surgery for postoperative neurological symptoms. Anesth Analg. juill 2009;109(1):265-271.

31. Sites BD, Beach ML, Spence BC, Wiley CW, Shiffrin J, Hartman GS, et al. Ultrasound guidance improves the success rate of a perivascular axillary plexus block. Acta Anaesthesiol Scand. juill 2006;50(6):678-684.

32. Casati A, Danelli G, Baciarello M, Corradi M, Leone S, Di Cianni S, et al. A prospective, randomized comparison between ultrasound and nerve stimulation guidance for multiple injection axillary brachial plexus block. Anesthesiology. mai 2007;106(5):992-996.

33. Chan VWS, Perlas A, McCartney CJL, Brull R, Xu D, Abbas S. Ultrasound guidance improves success rate of axillary brachial plexus block. Can J Anaesth. mars 2007;54(3):176-182.

34. Ota J, Sakura S, Hara K, Saito Y. Ultrasound-guided anterior approach to sciatic nerve block: a comparison with the posterior approach. Anesth Analg. févr

2009;108(2):660-665.

35. Liu F-C, Liou J-T, Tsai Y-F, Li AH, Day Y-Y, Hui Y-L, et al. Efficacy of ultrasound-guided axillary brachial plexus block: a comparative study with nerve stimulator-guided method. Chang Gung Med J. juin 2005;28(6):396-402.

36. Domingo-Triadó V, Selfa S, Martínez F, Sánchez-Contreras D, Reche M, Tecles J, et al. Ultrasound guidance for lateral midfemoral sciatic nerve block: a prospective, comparative, randomized study. Anesth Analg. mai 2007;104(5):1270-1274, tables of contents.

LISTE DES FIGURES

LISTE DES TABLEAUX

ANNEXES

Annexe 1 : Résumé présenté au congrès de l'American Society of Anesthesiology à Chicago en octobre 2011 à la session poster « Regional anesthesia and acute pain » et au « Resident Research Forum ».

American Society of Anesthesiologists

ANESTHESIOLOGY 2011

AMERICAN SOCIETY OF ANESTHESIOLOGISTS ANNUAL MEETING

A1738

October 19, 2011 8:00:00 AM - 11:00:00 AM Hall A1 South Area H

Learning Curves for Main Peripheral Nerve Blocks using Ultrasound Guidance in Residents

Naren Schinkel, M.D., Emmanuel Rineau*, M.D., Marc H. Maissiat, M.D., Elsa Parot-Schinkel, M.D., Jean L. NGuyen, M.D., Christian L'Hopitault, M.D., Laurent Beydon, M.D.,Ph.D.
Saint Leonard Private Center, Angers, France
University Hospital of Angers, France

Introduction

With the advent of ultrasound guidance for performing peripheral nerve blocks (PNB), regional anesthesia (RA) has experienced a major change in recent years. Many studies, comparing the use of a peripheral nerve stimulator (NS) with ultrasound guidance (US), seem to be in favour of US with a better quality of sensitive block, faster installation, shorter completion time, decreased amount of local anesthetics, and same or higher success rates. To our knowledge, there are no published studies establishing learning curves in a context of care of the main PNB using US. The aim of this study was to establish learning curves of the main PNB in a population of 8 inexperienced residents in anesthesiology.

Methods

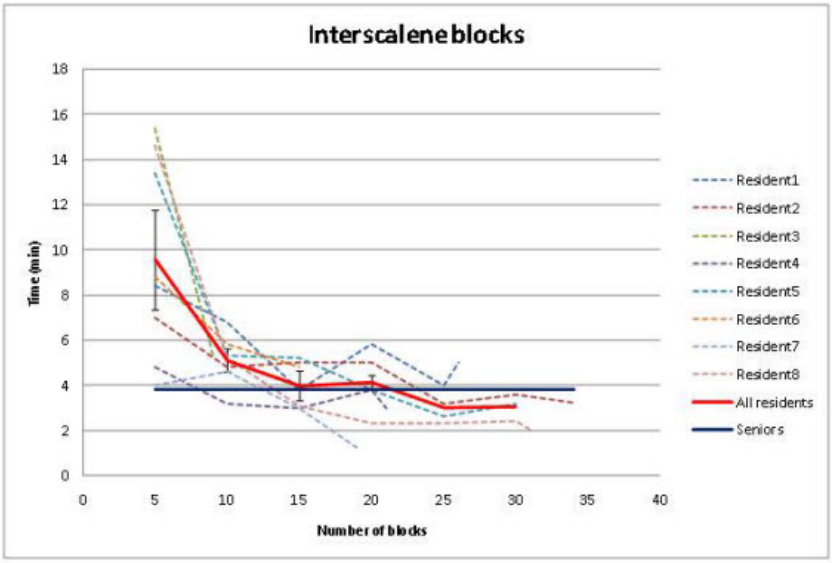
Prospective observational study with ethic committee approval. This study was performed between May 2009 and May 2011. Each resident was included for a period of 3 months. In the month before taking office, documents explaining the main functions of the ultrasound device and principles of ultrasound RA were provided to the resident. All pre-operative interscalene, axillary, femoral and sciatic (posterior approach) blocks performing by each resident were included in the chronological order. Each block was performed using US and NS in sentinel mode (<0.6mA). The primary endpoint was the execution time of the successful blocks from needle insertion to the beginning of the injection. The learning curve of each type of PNB and resident was constructed by performing the average of 5 consecutive blocks. The average execution time of each type of blocks by 2 anesthetists with expertise in RA using US was parallel calculated. A mean learning curve of residents for each PNB was then calculated and compared with the average execution time of the 2 experts. Second criterion was the number of mistakes made by residents (particularly the non-visualization of the needle tip and the unintentional mobilization). All mistakes per 10 successive PNB were added to achieve a curve estimating the number of mistakes made by the residents during their internship. The average curve of these mistakes by 10-PNB for all residents was then performed.

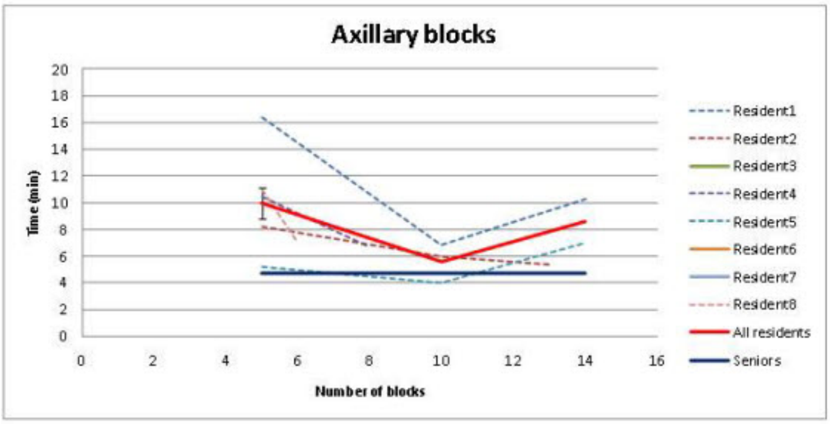
Results

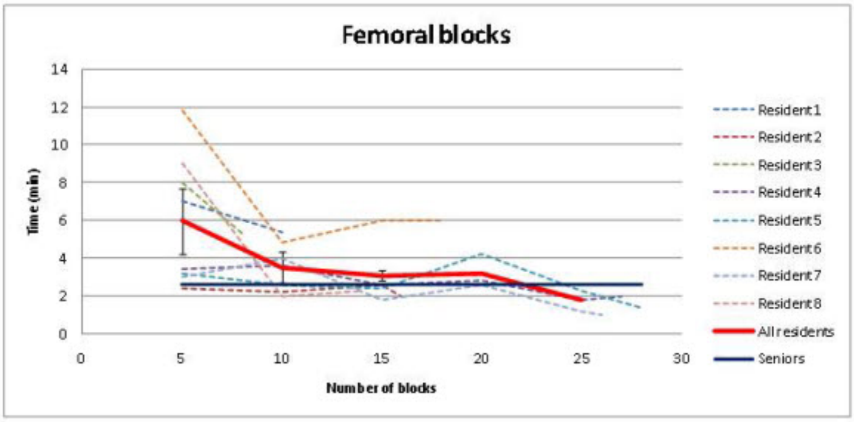
8 residents without experience in RA using US were included. 504 blocks were included (185, 63, 147, 109 respectively for interscalene, axillary, femoral and sciatic blocks). The learning curves crossed the average execution time of the experts between 20 and 25 blocks for interscalene and sciatic blocks, between 15 and 25 for femoral block. Insufficient axillary blocks (under 15) were performed to show a convergence with execution time of the experts. The final execution times obtained by residents compared with the average execution times of the 2 experts were 3.4±1.8 min versus 3.8±2.0 min for the interscalene block (p=0.6), 7.7±3.2 min versus 4.7±1.5 min for the axillary block (p=0.14), 1.8±1.1 min versus 2.6±1.1 min for the femoral block (p=0.05) and 3.7±1.6 min versus 4.2±2.6 min for the sciatic block (p=0.5). The resident mistakes decreased of 66% around 30 all included PNB. Progression without visualization of the needle was the most frequent mistake (36% of all errors).

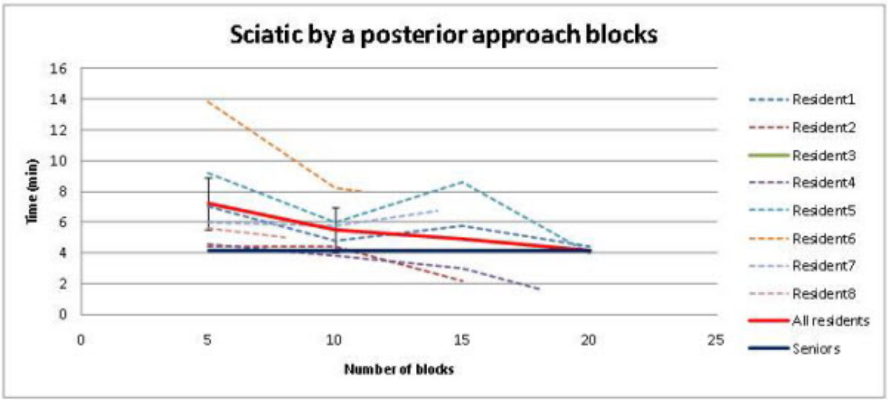
Conclusion

We have shown that a number between 20 and 25 of successive interscalene or sciatic blocks and between 15 and 20 of femoral blocks during the learning of RA using US was necessary to be as efficient as experienced physicians. Results for axillary blocks were not convincing probably because a lack of power. The RA learning was fastened by the use of US compared with NS. The routine use of ultrasound guidance seemed to be the best technique to learn regional anesthesia.


Interscalene blocks
Time (min)
Number of blocks
Resident1
Resident2
Resident3
Resident4
Resident5
Resident6
Resident7
Resident8
All residents
Seniors


Axillary blocks
Time (min)
Number of blocks
Resident1
Resident2
Resident3
Resident4
Resident5
Resident6
Resident7
Resident8
All residents
Seniors


Femoral blocks
Time (min)
Number of blocks
Resident1
Resident2
Resident3
Resident4
Resident5
Resident6
Resident7
Resident8
All residents
Seniors


Sciatic by a posterior approach blocks
Time (min)
Number of blocks
Resident1
Resident2
Resident3
Resident4
Resident5
Resident6
Resident7
Resident8
All residents
Seniors

Annexe 2 : Document adressé aux internes dans le mois précédent le stage en chirurgie orthopédique, expliquant les principes de l'anesthésie loco-régionale échoguidée pour les principaux blocs : interscalénique, axillaire, fémoral et sciatique.

Technique de réalisation des blocs nerveux périphériques

1 – Préambule

L'ensemble des blocs est réalisé sous guidage échographique avec une sonde linéaire de 10 MHz sur l'appareil d'échographie LOGIQ (General Electric Healthcare, Fairfield, USA) avec neurostimulation (Stimuplex HNS 12 Braün). La neurostimulation est utilisée en mode sentinelle avec une intensité de 0,5 mA, une fréquence de 2Hertz et une durée de 100 ms afin de confirmer l'origine nerveuse de la structure anatomique visualisée. Les aiguilles employées sont des aiguilles Pajunk isolées de 50 ou 100 mm simples ou permettant la mise en place d'un cathéter perinerveux.

Les solutions d'anesthésiques locaux (AL) employées pour les anesthésies de niveau chirurgical sont :

- la ropivacaïne (Naropéine®) à 0,75 % et 0,475 %.
- la lévo-bupivacaïne (Chirocaïne®) à 0,5 %.
- la lidocaïne (Xylocaïne®) à 1,5 et 2% adrénalinée ou non adrénalinée
- des mélanges équimolaires de lidocaïne à 2 % adrénalinée et de ropivacaïne à 0,75 % ou de lévo-bupivacaïne à 0,5 %.

Lorsque la solution n'est pas adrénalinée, du catapressan à 1 µg/Kg est adjoint au besoin.
Les solutions d'AL employées, pour les anesthésies à visée analgésique sont :

- la ropivacaïne (Naropéine®) à 0,2 %
- la lévo-bupivacaïne (Chirocaïne®) à 0,25 % ou 0,125 %

2 – Le bloc interscalénique

Chez un patient en décubitus dorsal, la tête tournée de 30° environ du côté opposé à la ponction, la sonde est appliquée à la base du cou afin de repérer la veine jugulaire interne et l'artère carotide. Puis la sonde est déplacée de façon céphalique et postérieure pour visualiser en coupe transversale le muscle sterno-clëido-mastoïdien, le défilé interscalénique avec les trois troncs primaires du plexus brachial. On maintien dans le champs ultrasonore les vaisseaux afin d'éviter une ponction vasculaire. On réalise également un enregistrement doppler pour préciser la localisation de l'artère vertébrale. La ponction est effectuée au bord interne de la sonde dans une direction antéro-postérieure dans le plan ultrasonore. Une réponse motrice de type nerf médian, nerf radial ou nerf musculo-cutané confirme l'origine nerveuse des structures visulisées. On injecte lentement et de façon fractionnée jusqu'à 30 ml de la solution d'anesthésique local choisie afin d'obtenir une bonne répartition autour des troncs nerveux dans l'espace interscalénique (signe du donut).

3 – Le bloc axillaire

Chez un patient en décubitus dorsal, le bras en abduction à 90°, coude fléchi ou non et la main en supination, la sonde est appliquée perpendiculairement au grand axe du bras au niveau du creux axillaire afin de repérer l'artère axillaire. On visualise les 3 nerfs : médian, radial et ulnaire situé au pourtour de l'artère. Le nerf musculo-cutané est en position plus antéropostérieure. Les 4 nerfs sont injectés individuellement après obtention d'une réponse motrice propre (nerf médian : contraction des muscles palmaires ; nerf radial : contraction des muscles de la loge postérieure de l'avant bras ; nerf ulnaire : contraction du muscle fléchisseur ulnaire du carpe ; nerf musculo-cutané : contraction du biceps brachial) par 5 à 10 ml de la solution d'AL choisie.

4 – Le bloc fémoral

Chez un patient en décubitus dorsal, la sonde est appliquée au niveau du pli inguinal perpendiculairement à l'axe de la cuisse afin de repérer l'artère et la veine fémorales. Le nerf est visualisé en position médiale par rapport aux structures vasculaires. L'aiguille est introduite au bord latéral de la sonde et maintenue dans le plan ultrasonore jusqu'à proximité du nerf fémoral. Une contraction du quadriceps avec ascension de la rotule confirme que la structure visualisée est le nerf fémoral. On injecte 20 ml de la solution d'AL choisie.

5 – Le bloc sciatique par voie postérieure

Chez un patient en décubitus ventral, la sonde est appliquée à la face postérieur de la cuisse perpendiculairement à l'axe de la cuisse. Le nerf fémoral est repéré comme une structure inhomogène de forme ovale présentant au cours de son trajet une division de niveau variable en 2 contingents. On repère le nerf sciatique avant sa division. L'aiguille est introduite au bord externe de la sonde puis maintenue dans le plan ultrasonore pour visualiser la progression jusqu'à la structure visée. Une réponse motrice de type tibiale (extension du pied) ou fibulaire (flexion du pied) confirmera qu'il s'agit du nerf sciatique. On injecte jusqu'à 30 ml de la solution d'AL choisie afin d'obtenir un l'image d'un nerf complètement entouré en redirigeant au besoin l'aiguille.

Référence

Delaunay L, Plantet F, Jochum D. Ultrasound and regional anaesthesia. Ann Fr Anesth Reanim. 2009 Feb;28(2):140-60

Annexe 3 : Document expliquant aux internes l'utilisation de l'échographe et l'aspect échographique des nerfs étudiés.

Utilisation de l'échographe
et aspect échographique des principaux nerfs

Vision générale du clavier:

Bouton "ON/OFF"

Bouton "Eject" à appuyer avant retrait d'un périphérique de stockage (USB)

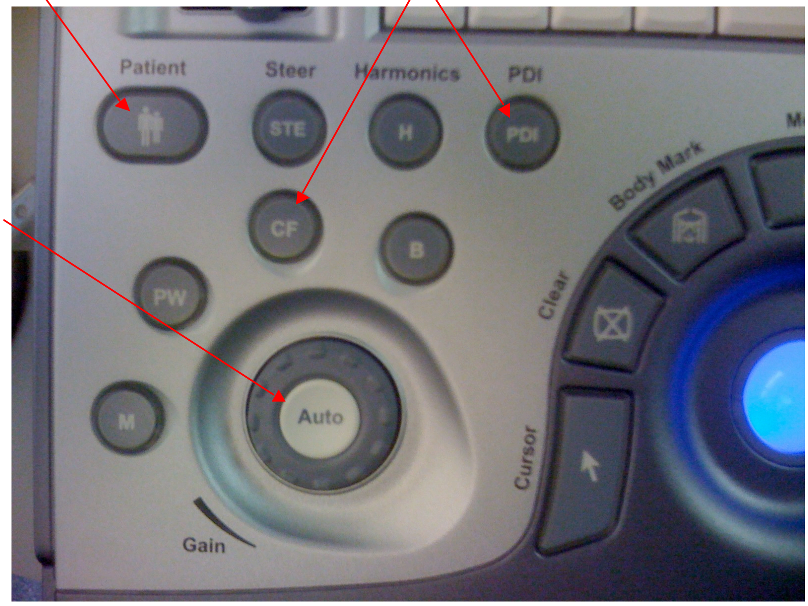
Affichage curseur "Roll" pad Bouton de validation

Partie de gauche:

Données patient

Doppler (2 types)

Gain



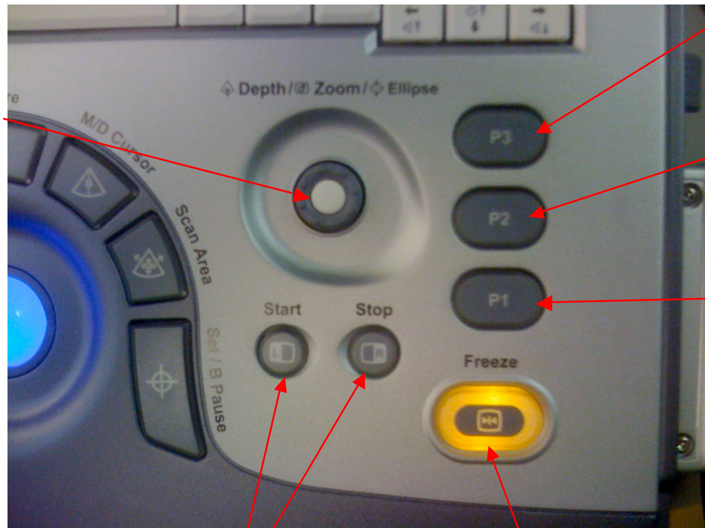
Partie de droite:

Enregistrement sur Périphérique en direct (DVD, clé USB, disque dur externe…

Profondeur

Copie sur imprimante (en dessous du clavier)

Enregistrement dans la mémoire de l'appareil



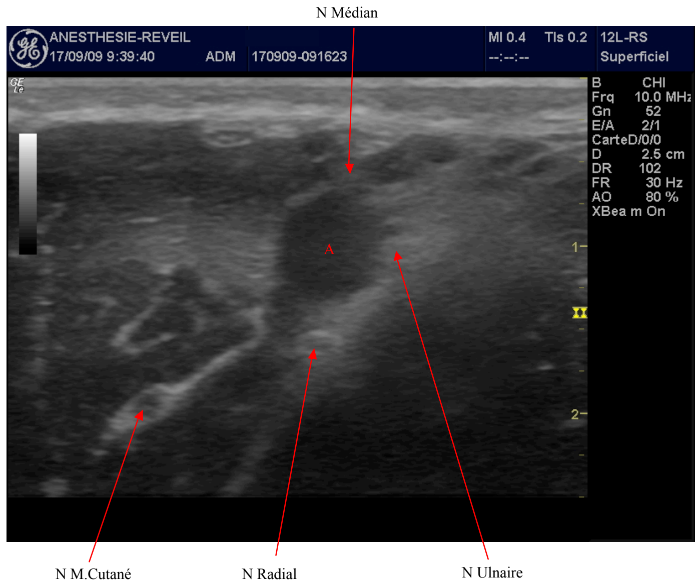
Partage d'écran

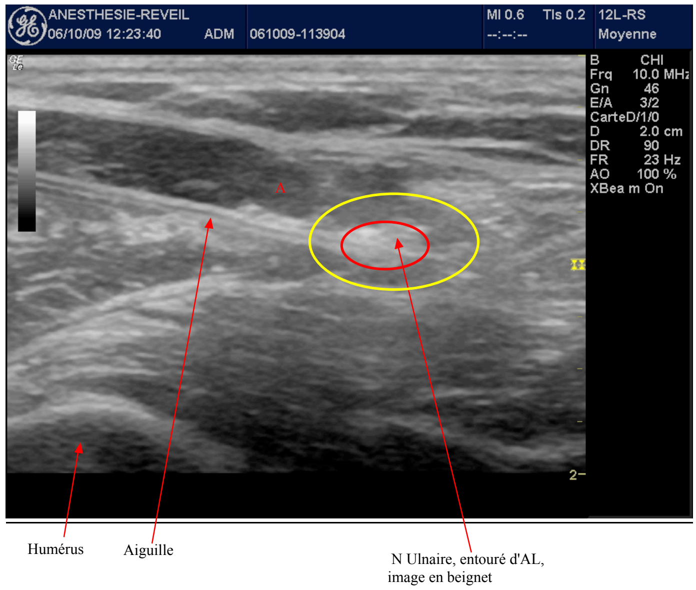
Gel écran, ici activé (possibilité enregistrement photo si activé, ou vidéo sinon)

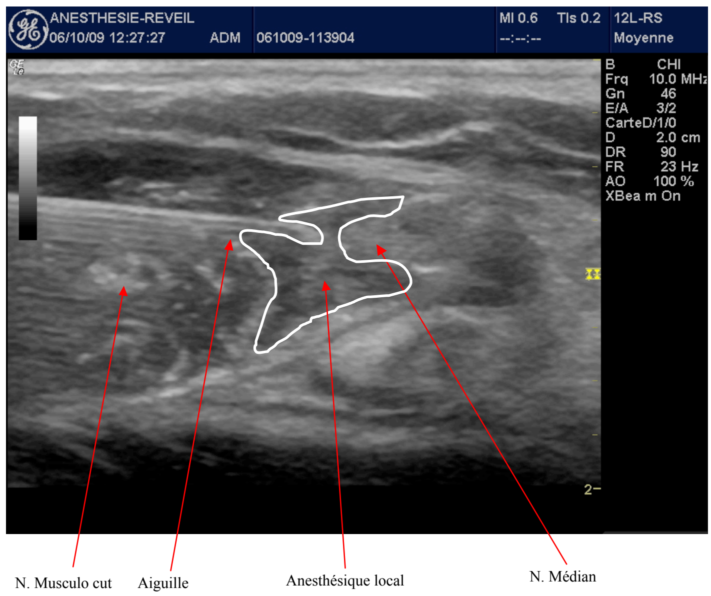
Ecran:


Focale
Fréquence de la sonde
ANESTHESIE-REVEIL
16/09/09 9:35:35
ADM
ESSAI1,
160909-090956
MI 0.34
TIs 0.3
12L-RS
Superficiel
B CHI
Frq 13.0 MHz
Gn 52
E/A 2/1
CarteD/0/0
D 3.0 cm
DR 102
FR 30 Hz
AO 80 %
XBea m On
0:0
(0.1:0.2 s)
Générique
(Z) % de sténose
(X) Volume
(C) Angle
(,) Ratio A/B
Fiche de travail Générique
B Mode
Menu
Zoom
16/09/09 9:56:45
start
Image copiée dans la mémoire de l'appareil.
Profondeur

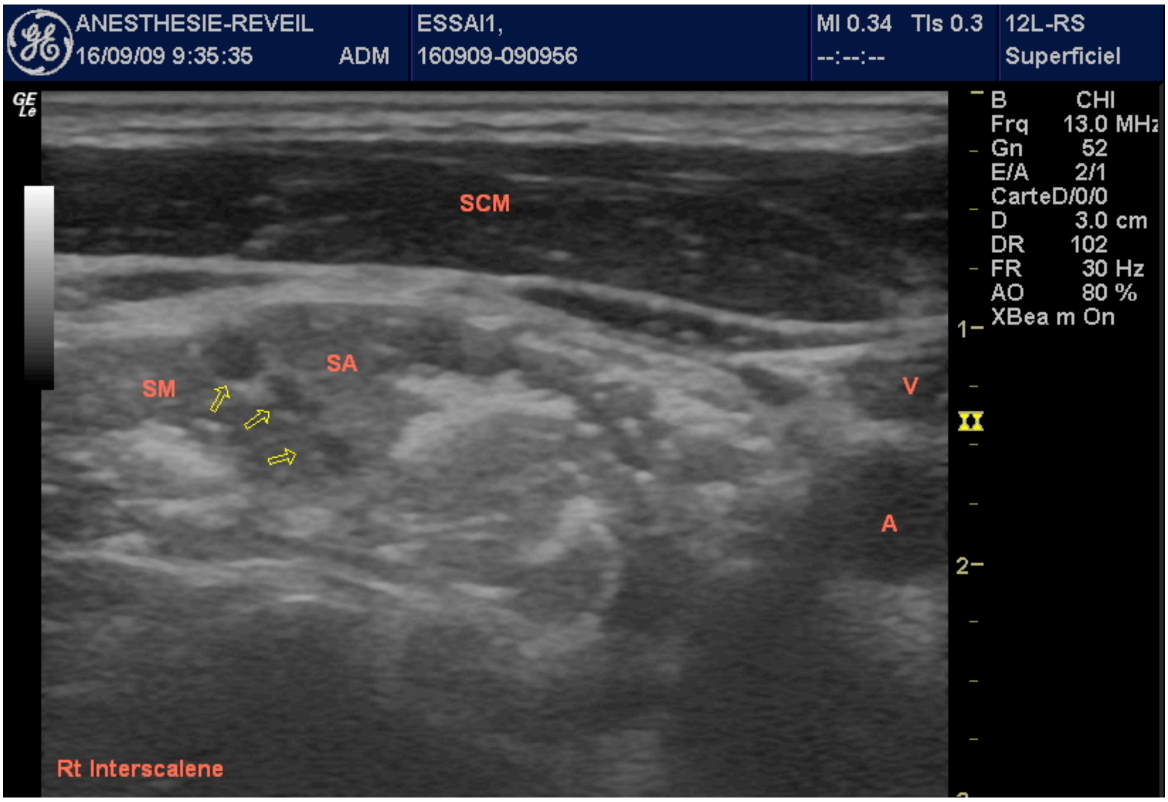
Bloc axillaire

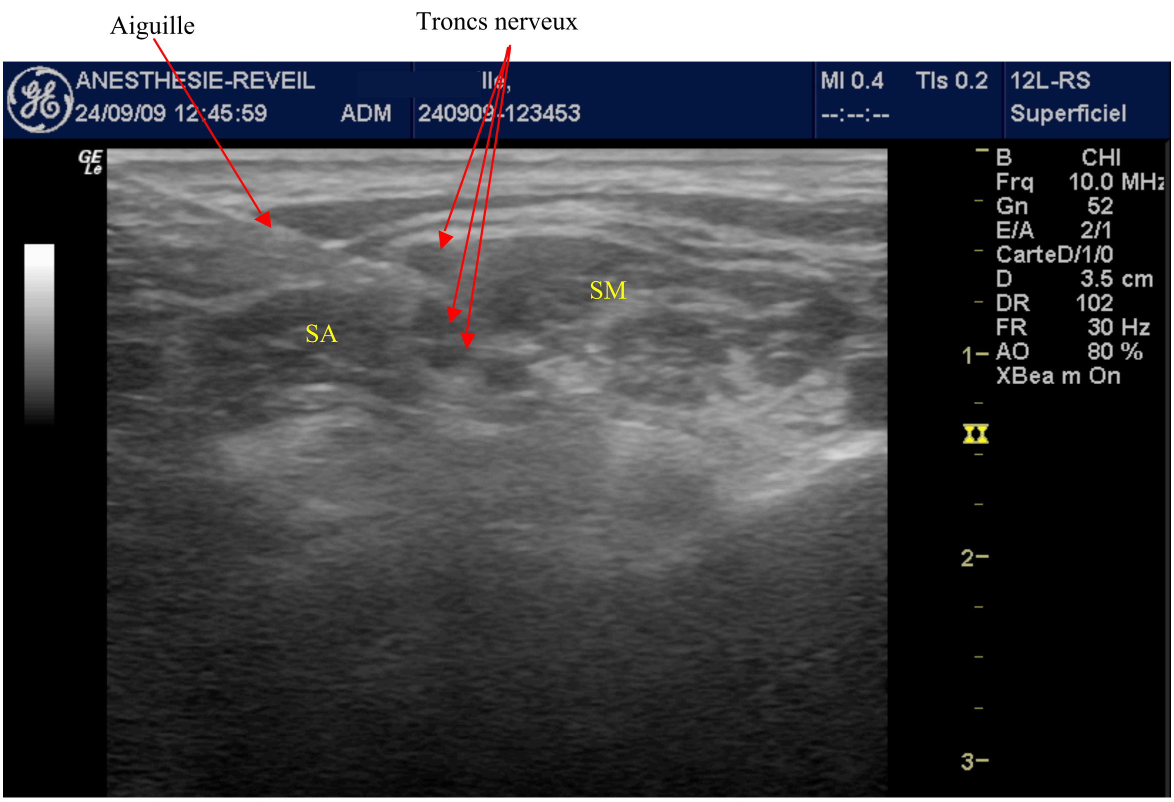




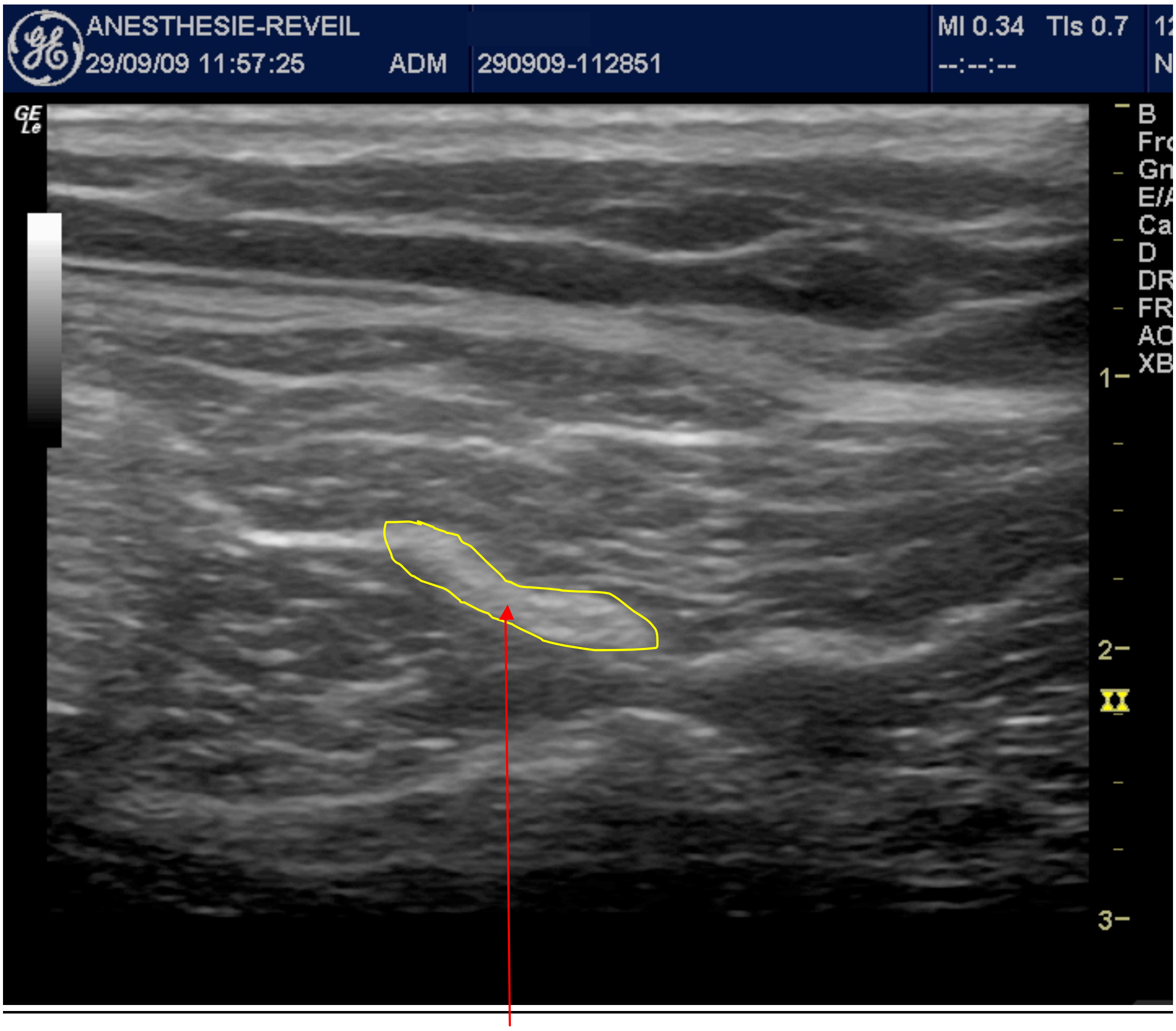


Bloc interscalénique



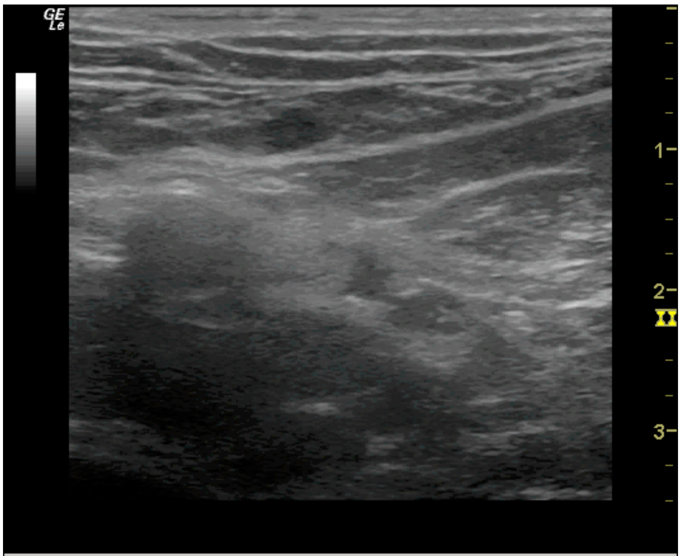


Bloc sciatique par voie postérieure

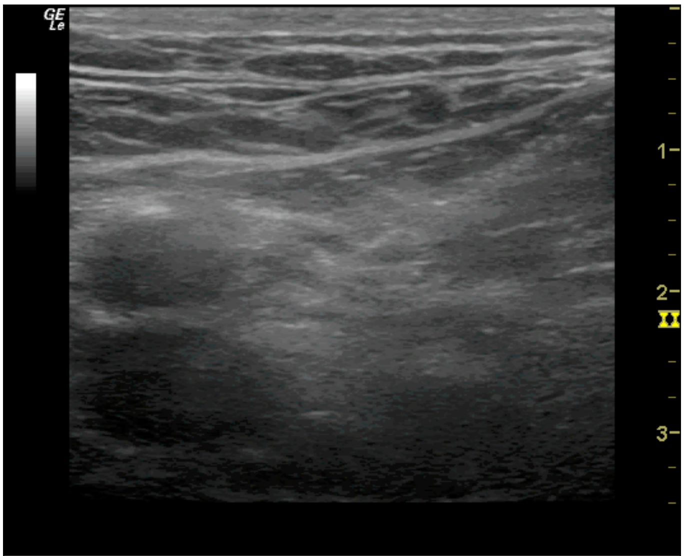


N. Sciatique

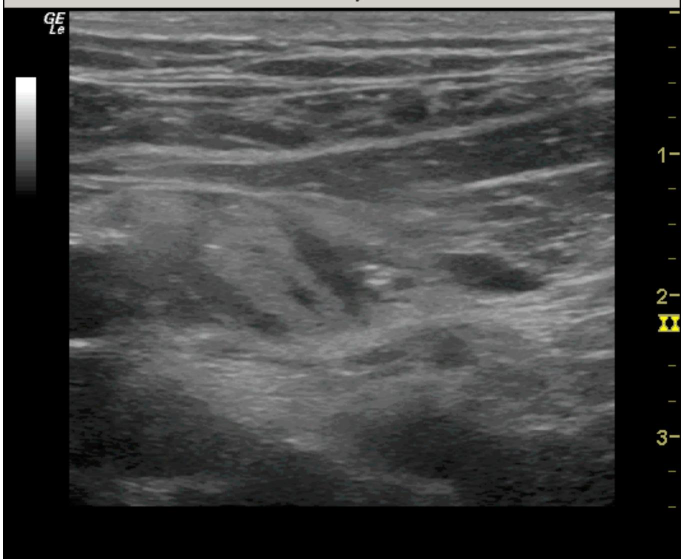
Bloc fémoral



BF approche aiguille.avi



BF en cours injection.avi



BF après injection.avi

Annexe 4 : Questionnaire de recueil des caractéristiques des internes.

Etude CAPPRI

Initiales interne: | _ | _ | Date:___________

---

1. Age de l'interne: | _ | _ | ans

2. Nombre de semestres validés: ______

3. Main dominante: Droitier ❒   Gaucher ❒

4. Expérience en **écho ALR**?   OUI ❒   NON ❒
   Si OUI, nombre approximatif de blocs sous échographie déjà réalisés:

   ❒ 0 – 5
   ❒ 5 – 20
   ❒ 20 – 40
   ❒ 40 – 60
   ❒ 60 – 80
   ❒ > 80

5. Expérience en ALR sous **neurostimulation**?   OUI ❒   NON ❒
   Si OUI, nombre approximatif de blocs sous neurostimulation déjà réalisés:

   ❒ 0 – 20
   ❒ 20 – 50
   ❒ 50 – 70
   ❒ 70 – 100
   ❒ > 100

6. Expérience dans l'utilisation de l'échographie pour d'autres indications?
   OUI ❒   NON ❒
   Si OUI, dans quelle(s) indication(s)?

   ____

   ____

   Et quelle fréquence d'utilisation?
   ❒ Quotidienne
   ❒ Hebdomadaire
   ❒ Mensuelle
   ❒ Occasionnelle

→

Tournez SVP

Expérience aux jeux vidéo (JV)

7. Etes vous toujours un joueur "en activité" ❐ OUI

   Si NON, passez à la question 8. ❐ NON

8. Jouiez vous aux JV durant les 5 dernières années, si vous n'êtes plus "actif"?

   ❐ OUI

   ❐ NON

   Si **NON**: **fin du questionnaire**.

9. Si vous avez répondu **OUI** à la question **7 OU 8**:

   a. Combien d'heures par semaine?

      ❐ < 1h
      ❐ 1 – 2h
      ❐ 3 – 4h
      ❐ 5 – 6h
      ❐ 7 – 8h
      ❐ ≥ 9h

   b. Type de jeux (cochez une et une seule des 3 cases suivantes en fonction de la catégorie de jeux la plus utilisée)

      ❐ Action / Aventure
      ❐ Simulation (avion, voiture, etc…)
      ❐ Sport / Stratégie / Réflexion

   c. Type de machine la plus fréquemment utilisée: (une seule case à cocher)

      ❐ PC
      ❐ XBOX / Playstation 2 ou 3 / PSP / Game Boy Advance / Nintendo DS
      ❐ Nintendo WII
      ❐ Autre

Annexe 5 : Cahier de recueil pour chaque bloc inclus.

Etude CAPPRI

Initiales interne: |_|_| Date:____________

Initiales du patient: |_|_|

1. Indication chirurgicale :

   ____

2. Bloc(s) effectué(s): ______________________________ Pose d'un KT? OUI ❐ NON ❐

   ______________________________ Pose d'un KT? OUI ❐ NON ❐

3. Réalisation d'une sédation? (hors prémédication) OUI ❐ NON ❐
   Si OUI, laquelle?

   Midazolam ❐ Alfentanil ❐ Fentanyl ❐ Propofol ❐

4. Nombre de replacement à la peau de l'aiguille (retour à la peau): _____

5. Nombre de ponctions cutanées (hors ponctions multiples prévues): _____

6. Anesthésiques locaux utilisés:
   a. Ropivacaïne 0,75%: ____________ mL
   b. Ropivacaïne 0;2%: ____________ mL
   c. Lévobupivacaïne 0,5%: ____________ mL
   d. Lidocaïne 1%: ____________ mL Adré? OUI ❐ NON ❐
   e. Lidocaïne 2%: ____________ mL Adré? OUI ❐ NON ❐
   f. Catapressan: ____________ µg

7. Volume total de préparation injecté: ____________ mL

8. IMS: _______ mA

9. Injection alors que PAS de contraction musculaire?
   (présomption échographique seule) OUI ❐ NON ❐

10. Durée de préparation/installation (du lavage des mains jusqu'à la ponction):
    ______ min

11. Durée de l'ALR (de la ponction jusqu'à la fin de l'injection): ______ min

12. EN maximale du patient pendant la procédure: _____ / 10

13. Complication per ou post ALR? OUI ❒ NON ❒
Si OUI, laquelle ou lesquelles?

____

____

14. **Diminution de sensibilité** sur le(s) territoire(s) nerveux bloqués par rapport à la valeur de base en controlatéral (**= 2**):

A H+10'	2	1	0
A H+20'	2	1	0
A H+30'	2	1	0

15. **Diminution de motricité** sur le(s) territoire(s) nerveux bloqués par rapport à la valeur de base en controlatéral (**= 2**):

A H+10'	2	1	0
A H+20'	2	1	0
A H+30'	2	1	0

16. Complément nécessaire? OUI ❒ NON ❒
Si OUI:
    a. Quel bloc? ____
    b. Quel(s) AL ? ____
    c. Quel volume? _____ mL

17. Réalisation d'une sédation per opératoire? OUI ❒ NON ❒
Si OUI, laquelle?

Midazolam ❒ Rémifentanil ❒ Kétamine ❒ Propofol ❒

18. AG nécessaire? (non prévue) OUI ❒ NON ❒

19. Réalisation d'une RA en plus du bloc? OUI ❒ NON ❒

20. Satisfaction du patient de retour en SSPI:

1 2 3 4 5 6 7 8 9 10

21. EN maximale en SSPI: ______ / 10

22. Quantité de morphine titrée en SSPI: ______ mg

<u>Prise en charge globale de l'acte et de la gestuelle :</u>
(à remplir de préférence par le senior)

Cocher "oui" ou "non", ou entourer les chiffres de 1 à 3 (1 = pas d'erreur, geste bien fait, 3 = grande difficulté dans la réalisation du geste ou du repérage)

23. Mauvaise reconnaissance du côté de l'image OUI ❒ NON ❒

24. Non visualisation du bout de l'aiguille à l'approche de la cible 1 - 2 - 3

25. Mobilisation non intentionnelle de la sonde (ex. glisse sur le gel) 1 - 2 - 3

26. Erreurs de repérage des structures anatomiques 1 - 2 - 3

27. Ne règle pas la qualité de l'image (gain) OUI ❒ NON ❒

28. Mauvaise préparation du matériel (oubli, besoin de quelque chose après le début de la ponction) OUI ❒ NON ❒

29. Malposition à l'écran des nerfs ciblés OUI ❒ NON ❒

30. Porte plus son attention sur ses mains ou la neurostimulation/neurostimulateur qu'à l'écran à l'approche de la cible OUI ❒ NON ❒

31. Mauvaise ergonomie:
    a. Dos "cassé" OUI ❒ NON ❒
    b. Tête tourné > 45° OUI ❒ NON ❒
    c. Aiguille tenue avec main non dominante OUI ❒ NON ❒

32. Echec visualisation mauvaise distribution des AL OUI ❒ NON ❒

33. Fatigue (changement de main, tremblement) OUI ❒ NON ❒

34. Changement d'opérateur/intervention du senior pour une erreur potentiellement dommageable OUI ❒ NON ❒