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REPORTS OF ORIGINAL INVESTIGATIONS

Complications of single-injection ultrasound-guided infraclavicular block: a cohort study

Complications d'un bloc infraclaviculaire échoguidé par injection unique: une étude de cohorte

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Abstract

Introduction *In recent studies on ultrasound-guided infraclavicular block (ICB), the authors have favoured a single injection posterior to the axillary artery rather than multiple injections; however, procedural complications and success rates associated with single-injection ultrasound-guided ICB are not well known. We undertook an observational study to evaluate the success rates of experienced and non-experienced operators performing ICBs and to identify the complications associated with ultrasound-guided single-injection ICB.*

Methods *We conducted an observational cohort study of all ultrasound-guided single-injection ICBs performed over a two-year period (2008-2010). We identified the subjects for our study using a local database and excluded patients younger than 18 yr and those who received a continuous ICB. Complications (non-neurological and neurological) and ICB success rates were the primary and secondary end points, respectively. We collected the following data from patients' charts: patient demographics, types of complications and their respective frequencies, and the experience of the clinician performing the ICBs, and we identified potential late complications by telephone interview. Using a seven-point Likert scale, two experts in regional anesthesia evaluated the likelihood of a relationship between the identified neurological signs or symptoms and the ICB. A neurologist then evaluated the complications identified as being potentially related to the ICB. Summary data were collated, and 95% confidence intervals (CI) were calculated.*

Results *We reviewed 627 ICB procedures, and 496 (79%) patients received telephone interviews. Most patients were males who had undergone either plastic or orthopedic surgery. Mepivacaine 1.5% was used in 96% of cases with a median volume of 30 mL [interquartile range 30-38]. We identified 131 cases of neurological signs or symptoms. Four cases were retained as possible links to the ICB, but they underwent complete resolution of symptoms at the time of evaluation. Two possible cases of local anesthetic toxicity were observed. There was a 93% success rate (95% CI 91 to 95) and the results were comparable between the experienced and the non-experienced operators (94% vs 93%, respectively).*

Author contributions All authors contributed substantially to the conception and design of the study, participated in data interpretation, and critically reviewed the manuscript. *Mylène Lecours*, *Simon Lévesque*, *Nicolas Dion*, *Marie-Josée Nadeau,* and *Annie Dionne* acquired the data. *Mylène Lecours*, *Simon Lévesque,* and *Alexis F. Turgeon* analyzed the data and drafted the manuscript.

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Discussion *We observed few complications associated with a single-injection ultrasound-guided ICB and a high success rate regardless of the operator's expertise. The technique appears to be reliable, easy to perform, and safe.*

Résumé

Introduction *Dans les études récentes portant sur les blocs infraclaviculaires (BIC) échoguidés, les auteurs ont privilégié une injection unique postérieure à l'artère axillaire plutôt que de multiples injections; toutefois, les complications liées à l'intervention et les taux de réussite associés aux BIC échoguidés par injection unique sont mal connus. Nous avons entrepris une étude observationnelle afin d'évaluer les taux de réussite d'opérateurs expérimentés et non expérimentés réalisant des BIC et d'identifier les complications associées aux BIC échoguidés par injection unique.*

Méthode *Nous avons réalisé une étude de cohorte observationnelle de tous les BIC échoguidés par injection unique réalisés au cours d'une période de deux ans (2008-2010). Nous avons identifié les patients pour notre étude à l'aide d'une base de données locale, en excluant les patients de moins de 18 ans et ceux recevant un BIC en continu. Les complications (non neurologiques et neurologiques) et les taux de réussite des BIC constituaient les critères d'évaluation primaires et secondaires, respectivement. Nous avons récolté les données suivantes des dossiers des patients: données démographiques des patients, types et fréquences respectives des complications, et expérience du clinicien réalisant le BIC; nous avons identifié les complications tardives potentielles en réalisant des entrevues téléphoniques. À l'aide d'une échelle de Likert en sept points, deux experts en anesthésie régionale ont évalué la probabilité d'une association entre les signes ou symptômes neurologiques identifiés et le BIC. Un neurologue a ensuite évalué les complications identifiées comme étant potentiellement liées au BIC. Les données agrégées ont été assemblées, et des intervalles de confiance (IC) de 95 % calculés.*

Résultats *Nous avons passé en revue 627 interventions de BIC, et 496 (79 %) des patients ont également été interrogés par téléphone par la suite. La plupart des patients étaient des hommes ayant subi une chirurgie plastique ou orthopédique. Dans 96 % des cas, de la mépivacaïne 1,5 % avait été utilisée avec un volume moyen de 30 mL [écart interquartile 30-38]. Nous avons identifié 131 cas de signes ou symptômes neurologiques. Quatre cas ont été retenus comme ayant des liens possibles avec le BIC, mais les symptômes s'étaient complètement résolus au moment de l'évaluation. Deux cas possibles de toxicité de l'anesthésique local ont été observés. Le taux de réussite était de 93 % (IC 95 % 91 à 95) et les résultats étaient comparables entre les opérateurs expérimentés et non expérimentés (94 % vs. 93 %, respectivement).*

Discussion *Nous avons observé peu de complications associées au BIC échoguidé par injection unique et un taux de réussite élevé indépendamment de l'expertise de l'opérateur. La technique semble être fiable, facile à réaliser et sécuritaire.*

Ultrasound-guided infraclavicular block (ICB) provides adequate anesthesia for arm and hand surgery.[1] Two approaches are described in the literature: multiple injections or a single injection posterior to the axillary artery.[2,3] Results of a recent randomized controlled trial conducted by our group favoured a single injection posterior to the axillary artery rather than multiple injections. Indeed, when performed by anesthesiologists experienced in ultrasound-guided infraclavicular blocks, the single-injection technique has a high success rate as well as a shorter performance time.[2] These results were subsequently confirmed in another randomized controlled trial.[4] Experienced operators performed the ultrasound-guided ICB faster with a single-injection technique than with a triple-injection technique, and they were more successful at achieving a brachial plexus block at 20 min.[4]

Despite the ease of the technique, its success rate and fast onset, several concerns remain when performing a single-injection ultrasound-guided ICB. Indeed, the fascial "click" described during the block procedure, suggestive of a good-quality block,[5] may also raise some concerns regarding the safety of the technique. Although the exact nature of the anatomic structure(s) responsible for this tactile feeling is not well understood, patients frequently report a transient tingling sensation in the upper extremity, which may be secondary to penetration of the epineurium of the brachial plexus components. Moreover, in a recent animal study, forced needle advancement during needle-nerve contact has been shown to correlate with the severity of the structural nerve injury.[6] Although few complications have been reported with single-injection ultrasound-guided ICB, most studies reported a relatively small sample size (< 60 patients) and were not large enough to evaluate the incidence of complications.[2,4,7-9] In a study reporting on neurological complications, all types of blocks were considered, and only 122 of the blocks were ICBs.[10] Accordingly, the safety of a single-injection ultrasound-guided ICB has not been fully established.

We undertook an observational study with the primary objective to evaluate the rate of complications associated with ultrasound-guided single-injection ICBs. Our secondary objectives were to evaluate the overall success rate of ultrasound-guided single-injection ICBs in our academic

centre and to compare the success rate achieved by experienced operators with that achieved by non-experienced operators. We hypothesized that this technique is associated with few neurological and non-neurological complications, the technique is easy to learn, and it is associated with a high block success rate.

Methods

Following approval from the Research Ethics Committee (REC) of the Centre Hospitalier *Affilié* Universitaire de Québec (CHA) (Hôpital de l'Enfant-Jésus), we conducted an observational cohort study of ultrasound-guided ICBs. This work was conducted in an academic level I trauma centre (CHA – Hôpital de l'Enfant-Jésus) in Québec City, Québec. The study involved an extensive chart review and structured telephone interviews with patients who underwent single-injection ultrasound-guided ICBs for elective and urgent surgeries (from 0800 hr to 1600 hr during week days) during January 2008 to December 2009. As part of the REC approval and oversight, verbal informed consent was obtained from each patient prior to each telephone interview. All single-injection ultrasound-guided ICBs performed during the study period were identified using a clinical database and considered for inclusion. The data in the clinical database were collected by anesthesia assistants (respiratory therapists) working at the block room. We excluded multiple-injection ICBs, non-ultrasound-guided ICBs, continuous ICBs, ICBs performed on patients under 18 yr of age, and ICBs performed during non-prime-time elective hours.

Ultrasound-guided ICB technique

Since our study on ultrasound-guided ICBs was published in 2007,[2] the single-injection ultrasound-guided ICB has become our standard regional anesthetic technique for brachial plexus block. The technique we developed and describe in our study is the technique we taught to our colleagues and is the very technique we teach to our residents in anesthesia. The first step in performing this technique is to place a linear probe in the deltopectoral groove along the sagittal plane medial to the coracoid process. This facilitates best visualization of the axillary artery in the short-axis below the pectoral muscles. Using an in-plane technique, a 20-G Tuohy needle (B. Braun, Bethlehem, PA, USA) is then inserted on the cephalad side of the probe and directed toward the posterior side of the axillary artery. Once a fascial "click" is felt and there is negative aspiration for blood, the anesthetic solution can be injected in fractional doses. The operator should strive for a U-shaped distribution of the local anesthetic around the axillary artery.

Data collection

First, three investigators (M.L., S.L., N.D.) used a standardized case report form to collect the following data from the patients' charts (paper format): demographics (age, sex, weight, height, body mass index, American Society of Anesthesiologists [ASA] physical status), relevant medical comorbidities (pulmonary disease, diabetes, coagulation disorder, neurological disease), medications that alter coagulation, coagulation laboratory tests (international normalized ratio, activated partial thromboplastin time, platelet count, platelet function analysis [PFA-100®]), presence of preoperative neurological symptoms specified in the medical record (paresthesiae, sensory or motor deficits), anesthesia data (clinician performing the ICB, type of local anesthetic used for the ICB, concentration and volume of the local anesthetic, incidence of paresthesia and blood aspiration while performing the ICB, additional blocks performed, and conversion to general anesthesia), and surgery data (type and duration of surgery, presence of a tourniquet and its duration, infiltration of the surgical site with local anesthetics). The investigators also recorded signs or symptoms noted in the anesthesia chart or disclosed during the follow-up visit which suggested potential complications.

Second, one investigator (M.L.) attempted to contact all patients who underwent an ICB and used a standardized telephone interview process (Appendix) to collect additional information on late or potentially missed ICB complications. Up to three attempts were made to reach the patient, with at least 24 hr between each attempt. The telephone calls were carried out at variable time periods during January to April 2010 after the blocks were performed.

Definition of complications

We classified the complications into three groups: 1) local and regional complications (hematoma, ecchymosis, erythema, local infection, and pneumothorax), 2) complications related to systemic toxicity of the local anesthetic solution, and 3) neurological complications from the procedure. Local and regional complications were identified from both the charts and the telephone interviews, while complications relating to systemic toxicity of the local anesthetic solution were identified only from the charts. Neurological complications were considered based on information obtained from both the charts and the telephone interviews. One of the investigators (M.L.) initially identified potential neurological complications by assessing all postoperative neurological signs or symptoms, whether or not they were present before surgery. Next, two experts in regional anesthesia (S.L., N.D.) independently assessed the probability

that these neurological signs or symptoms were related to the ICB using a seven-point Likert Scale (1 = certainly related; 2 = probably related; 3 = possibly related; 4 = uncertain; 5 = possibly not related; 6 = probably not related; 7 = certainly not related. The lower score (highest probability of relationship with the block) between the two assessors was used for analysis, except when a difference greater than or equal to two points was observed. In these situations, the two assessors discussed the case between themselves to reach an agreement. All potential cases of neurological complications, defined as a score from 1-4 on the Likert Scale, were then evaluated by a neurologist (A.D.) with sub-specialized training in peripheral nerve pathology and electrophysiology. The neurologist performed the evaluation deemed necessary (physical examination, nerve conduction studies, or electromyogram) based on the patient's reported history in order to confirm or negate the relationship between the observed neurological signs or symptoms and the ICB.

Definition of a successful ICB

In our view, an ICB is considered successful whenever surgery is performed without additional anesthesia supplementation (i.e., regional anesthesia, general anesthesia, or local infiltration by the surgeon). Clinicians are considered experienced when they have performed a minimum of 30 ultrasound-guided single-injection ICBs. This definition is based on a study of first-year residents' learning curves using different regional anesthetic techniques.[11] The learning curve for the brachial plexus block reached a near plateau around 30 blocks performed.[11] In our study, when non-experienced operators performed ICBs, they were most often supervised by a certified anesthesiologist having fellowship training in regional anesthesia and considerable experience in ultrasound-guided single-injection ICBs (S.L., N.D., M.J.N.).

Sample size

We used a sample of convenience ($n = 627$) corresponding with the entire data set of potentially eligible subjects included in our clinical database (started in January 2008). Based on a 1.5% complication rate, i.e., the observed incidence of neurological complications following axillary block in a recent study,[9] this sample size would generate about 1% precision (95% confidence interval [CI] 0.01 to 2.8) around this incidence.

Data analysis

All analyses are descriptive. Continuous variables are presented as means with 95% CIs or medians with interquartile ranges (IQR). Categorical variables are presented as proportions with 95% CIs. The denominator used to calculate the rates of the local and neurological complications was the total number of ICBs analyzed by telephone interview. The denominator used to calculate the rate of local anesthetic toxicity and the success rate was the total number of ICBs analyzed using the medical records.

Results

Over the study period, 627 ultrasound-guided single-injection ICBs were identified within our local clinical database and included in this study, and all medical records of the respective patients were reviewed. Among them, 496 patients were reached by phone and successfully completed the structured telephone interview. Telephone numbers could not be obtained for 71 patients; 59 patients could not be reached after three attempts, and one patient declined the invitation to participate.

Demographic data are shown in Table 1. Mepivacaine (mostly in a concentration of 1.5%) was the only local anesthetic used in at least 96% (600/627) of the ICBs performed using a median volume of 30 mL (IQR 25-75% [30-38]). Paresthesiae were noted during the performance of 7% (43/627) of the ICBs, and blood aspiration was observed in 3% (16/627) of them. Most ICBs were performed by non-experienced operators (76%, 478/627). The main indication for surgery was traumatic injury (62%, 389/626). One surgery was cancelled after the ICB had been completed. The mean (standard deviation) duration of surgery was 38 (28) min and a tourniquet was used in 69% (431/626) of surgeries for a mean duration of 39 (24) min.

Table 1 Patients demographics

	$n = 627$
Male/Female	424 / 203
Age (yr)	53 (18)
BMI	26 (4)*
ASA physical status	
I	221 (35%)
II	372 (59%)
III	34 (5%)
Diabetes	42 (7%)
Coagulation disorder	0

*BMI was calculated for 594 cases as either weight or height was unavailable for 33 cases; Values are proportions (%) or mean (standard deviation). BMI = body mass index; ASA = American Society of Anesthesiologists

Table 2 Potential causal links between identified neurological events and single-injection ultrasound-guided infraclavicular blocks

Score on Likert Scale	Number of neurological events
1: certainly related	0
2: probably related	2
3: possibly related	5
4: uncertain	12
5: possibly not related	16
6: probably not related	44
7: certainly not related	52

Non-neurological complications

None of the cases was complicated by pneumothorax, and there were no reports of infection at the site of needle puncture. We observed 14 (3%) cases of mild local erythema, ecchymosis, or hematoma (95% CI 2 to 5), and two cases (0.3%) of possible local anesthetic toxicity were identified (95% CI 0 to 1). The first patient was a 59-yr-old male without existing comorbidities who complained of perioral paresthesiae. The clinician who performed the block noted that several millilitres of the anesthetic solution (1.5% mepivacaine 30 mL) may have been injected intravascularly. This patient received midazolam 5 mg *iv* for conscious sedation during the procedure. The second case involved a 42-yr-old ASA class I female. She reported visual and hearing disturbances and experienced nausea ten minutes after the ICB had been performed with 1.5% mepivacaine 35 mL. During the procedure, she received cumulative doses of midazolam 1.5 mg *iv* and sufentanil 2.5 μg *iv* for conscious sedation. Blocks for both patients were successful, and neither developed signs of central nervous system or cardiovascular toxicity.

Neurological complications

Postoperative neurological signs or symptoms were identified in 131 patients. Following independent evaluations by the two experts, 19 cases were considered as certainly, probably, or possibly related to the ICB, or it was indeterminate whether the signs could be related to the ICB (scores from 1-4 on the Likert Scale) (Table 2). The signs in 15 of these patients were considered not to be linked to the ICB. The electromyogram was negative in two patients, and in 13 others, the signs were considered not to be associated with the ICB (according to the consulting

Table 3 Description of the four cases of neurological complications potentially related to the ICB

Cases	Patients' characteristics	Description of the performance of the ICB	Characteristics of the surgery	Neurological symptomatology
1	Male 56-yr-old 95 kg, 178 cm ASA II No diabetes	Expert No paresthesia No blood aspiration	Digitopalmar fasciectomy of the 4th and 5th digits Duration 20 min Tourniquet 13 min	Weakness biceps to elbow Duration > 1 yr Resolved
2	Male 63-yr-old 82 kg, 183 cm ASA II No diabetes	Non-expert No paresthesia No blood aspiration	Excision of plate and screws on the 4th metacarpus Duration 20 min No tourniquet	Weakness/pain/paresthesia in the shoulder Duration > 6 months Resolved
3	Male 65-yr-old 80 kg, 168 cm ASA II No diabetes	Non-expert No paresthesia No blood aspiration	Dupuytren surgery Duration 38 min Tourniquet 22 min	Weakness/pain in the shoulder Duration < 1 month Resolved
4	Male 53-yr-old 100 kg, 183 cm ASA I No diabetes	Non-expert No paresthesia No blood aspiration	Digitopalmar fasciectomy of the 5th digit Duration 35 min Tourniquet 25 min	Numbness in the hand and arm Duration 2 days Resolved

ICB = infraclavicular block; ASA = American Society of Anesthesiology physical status classification; Expert = clinician who performed a minimum of 30 ultrasound-guided single-injection ICBs; Non-expert = clinician who performed less than 30 ultrasound-guided single-injection ICBs

neurologist and based on patient history and physical examination). Only four cases were considered potentially related to the ICB, leading to a neurological complication rate of 0.8% (95% CI 0 to 2) (Table 3). The signs and symptoms in all four patients were transient and could not be clearly linked by the neurologist since they all had resolved at the time of assessment. Importantly, none of the four cases was associated with paresthesiae or evidence of blood aspiration during the block procedure.

Success rate

The overall success rate of the ultrasound-guided single-injection ICB was 93% (95% CI 91 to 95). The experienced operators (five certified anesthesiologists and four residents) achieved a success rate of 94% (95% CI 89 to 98), while the non-experienced operators (27 certified anesthesiologists and 23 residents) achieved a success rate of 93% (95% CI 90 to 95).

Discussion

In this single centre observational cohort study, we observed relatively few complications associated with ultrasound-guided single-injection ICBs. All local complications were considered minor; no case of pneumothorax, compressive hematoma, or abscess was observed, and the two cases of potential local anesthetic toxicity resolved rapidly and without sequelae. The overall rate of neurological complications was less than 1%, and the four identified cases involved only transient symptoms. This systematic evaluation of the success rate and complications associated with ICBs using a single-injection ultrasound-guided technique provides information relevant to the practicing clinician.

It is important to reflect on the observed neurological complication rate associated with the ICBs in our series compared with that observed using multiple-injection ultrasound-guided ICBs. In a recent prospective cohort study, new neurological symptoms after ultrasound-guided peripheral nerve blocks for upper and lower limb elective orthopedic surgeries were assessed by telephone interviews. The authors identified nine cases of neurological complications in 122 ultrasound-guided ICBs using a triple-injection technique.[10] One case was thought to be related to the ICB; five others were judged to be related to the surgery, and three other cases had an unclear etiology.[10] The study was designed to evaluate only neurological complications, and the small number of ICBs reviewed for potential complications precluded assessment of rare events and complication rates. In another study, the safety of the single-injection infraclavicular block was evaluated when performed with nerve stimulation. Amongst 248 patients, no complication was noted at the follow-up visit, although 27% of patients in this series reported some complaints at the 24-hr follow-up telephone call.[12] In this study, there was only one follow-up telephone call at 24-hr postoperatively, and chart review was the only means used to assess prolonged symptoms. The complication rate in our study is similar to that reported using other approaches to brachial plexus block. Indeed, in a systematic review of prospective and retrospective studies reporting neurological complications following all types of regional anesthesia, estimated rates of peripheral neuropathy following brachial plexus blockade are less than 3% (1.48% for axillary block and 0.03% for supraclavicular block).[13]

Our study has several limitations. Despite the reasonably strict methodological approach, including a duplicate evaluation of data collected from patients' charts and structured telephone interviews, we cannot exclude that the observed complication rates may have underestimated the results due either to the non-reporting of events or to incomplete documentation on the patients' charts. Nevertheless, we consider it unlikely that clinically important complications were either neglected and not recorded in the chart or would not have been identified by the patient during the telephone interview. We recognize that some data are missing due to our inability during the study to contact all patients for a telephone interview, which may have underestimated the overall incidence of complications. Another potential limitation is our inability to adjust for non-access to an experienced anesthesiologist (> 30 blocks) for supervision when required, which may have influenced the block success rates. On the other hand, postoperative neurological symptoms are likely to be multifactorial; identifying the exact etiology of the symptoms is a difficult task that is subject to uncertainty. When regional anesthesia is performed, the etiology of most postoperative neurological symptoms are deemed to be surgical in close to 90% of cases.[14] In order to be as objective as possible in our study, we first opted to identify every postoperative neurological sign or symptom, whether or not present preoperatively, and then to evaluate any potential causal link with the ICB. Since most ICBs were performed for traumatic injuries, we cannot exclude that a significant number of postoperative signs or symptoms were due to the initial trauma, the surgery, or the ongoing development of a complex regional pain syndrome. Similarly, because we do not routinely perform a specific preoperative neurological assessment at our centre, we may have underestimated the prevalence of preoperative neurological symptoms; consequently, some of the observed signs and symptoms may have been present before the procedure. These hypotheses may account for the high number of potential events observed in the first phase of evaluation. Despite our approach to the assessment of the relationship between the neurological symptoms and the

ICB, there is a subjective element that must be considered. Finally, most neurological complications were identified from telephone interviews. Since these interviews were performed at a variable period after the ICB and surgery, a potential recall bias was introduced.

In our study, we observed local complications, complications related to the toxicity of the local anesthetic solutions, and neurological complications associated with the performance of ultrasound-guided ICB using a single-injection technique. Nevertheless, all observed complications were transient and the patients recovered completely. The high success rate of the ICB for both the experts and non-experts highlights the ease of its performance as well as its potential fast learning curve. In summary, ultrasound-guided ICB performed with a single injection posterior to the axillary artery is a reasonably safe technique associated with a high success rate regardless of the expertise of the anesthesiologist performing the block.

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Appendix

Structured phone interview

In the days following your surgery…

1) Did you notice a weakness in your hand or arm that was not present before surgery?

If so, how long did it last?

☐ < 1 week ☐ 1 week to 1 month ☐ 1 to 6 months ☐ > 6 months

2) Did you feel a loss of sensation or an abnormal sensation resembling electric shocks, tingling, burning or numbness in your hand or arm?

If so, how long did it last?

☐ < 1 week ☐ 1 week to 1 month ☐ 1 to 6 months ☐ > 6 months

3) Have you had difficulty breathing?

4) Did you notice a swelling, redness, or blood or pus flow at the site of injection?

If so, please specify:

_____

5) Did you need to consult a physician in addition to a planned follow-up visit?

Yes No

If so, why?

_____

Appendix

Structured phone interview (original version in French)

Dans les jours suivants votre chirurgie…

1) Avez-vous remarqué une faiblesse de la main ou du bras qui n'était pas présente avant la chirurgie?

Si oui, pendant combien de temps?

☐ < 1 semaine ☐ 1 semaine à 1 mois ☐ 1 à 6 mois ☐ > 6 mois

2) Avez-vous ressenti une perte de sensation ou une sensation anormale sous forme de chocs électriques, de picotements, de brûlures ou d'engourdissements à la main ou au bras?

Si oui, pendant combien de temps?

☐ < 1 semaine ☐ 1 semaine à 1 mois ☐ 1 à 6 mois ☐ > 6 mois

3) Avez-vous eu de la difficulté à respirer?

4) Avez-vous remarqué un gonflement, une rougeur ou un écoulement sanguin ou purulent au site où vous avez été piqué?

Si oui, précisez : _____

5) Avez-vous eu à consulter un médecin, excluant un rendez-vous de suivi déjà prévu?

Oui Non

Si oui, pourquoi?

_____

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