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# The substantial impact of ultrasound-guided regional anaesthesia on the clinical practice of peripheral nerve blocks

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## Abstract

**Background:** Ultrasound-guided (US-guided) regional anaesthesia has gained worldwide popularity in recent years owing to the benefits the method offers to patients. The 1st Department of Anaesthesiology and Intensive Care of Warsaw Medical University was one of the first centres in Poland to employ US-guided peripheral nerve blocks (PNB) on a routine basis. The technique was incorporated into the institution's clinical practice from 2007. The purpose of this study was to retrospectively assess changes in the clinical practice of US-guided versus non US-guided PNBs over six years of experience with the technique.

**Methods:** Retrospective analysis assessing the prevalence of PNB methods, local anaesthetic (LA) injection techniques (i.e. single injection vs. multiple), LA volumes used, success rates and the incidence of complications.

**Results:** This study included 4,066 PNBs performed between January 2006 and June 2012. The results showed systematic growth in the prevalence of US-guided blocks in the total number of PNBs, from 8.6% in 2007 up to 53.3% in 2012. The mean LA volume used in PNB was significantly lower in US-guided blocks compared to traditional PNB techniques (respectively, 21.83 mL vs. 31.41 mL, $P < 0.05$) without a decrease in the success rate (respectively, 76% vs. 74%, $P > 0.05$). A shift in the prevailing block technique from single injection to multiple injections was observed, regardless of the nerve location technique employed (from 29% up to 84% of PNBs performed using multiple injection technique).

**Conclusions:** The use of ultrasound optimizes the technique of peripheral blocks and the amount of local anaesthetic used. Ultrasonography does not affect the safety of peripheral blocks.

**Key words:** regional anaesthesia, peripheral nerve blocks; regional anaesthesia, techniques; regional anaesthesia, ultrasound

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Peripheral nerve blocks (PNBs) provide effective anaesthesia of areas of the body innervated by individual plexuses or single nerves. This effect is accomplished by inhibiting nerve conduction using local anaesthetics (LAs). PNBs provide efficacious and long-term analgesia in the perioperative period. Unlike general anaesthesia, PNBs are minimally invasive procedures that don't impair patient consciousness. Properly administered PNBs exert a negligible effect on the cardiovascular and respiratory systems. Owing to the limited and predictable block extent, as well as the lack of systemic effects, patients can be quickly ambulated and rehabilitated postoperatively. The most severe peripheral block-related risk is LA toxicity, yet its incidence is low [1].

The precise administration of LAs in the proximity of target nerves is essential to benefit from the PNB and to diminish its risks. Therefore, research efforts have been focused on designing optimal methods of nerve location. Anatomical landmarks as well as motor and sensory reactions associated with needle manipulations in body tissues have been used to guide LA injections and obtain a successful block. However, these methods have often failed. Because they depended on a subjective assessment by a physician and

good communication with the patient, high efficacy and reproducibility of the anaesthesia couldn't be guaranteed. This situation changed to some degree once the technique of electrical nerve stimulation (NS) was introduced into clinical practice. This modality improved the efficacy of anaesthetic management by providing objective information concerning nerve position. For these reasons, PNBs performed using traditional identification methods were perceived as a kind of 'art' that could be mastered only by a small community of 'artists'.

The attitude towards PNBs changed substantially when ultrasonography was introduced to the clinical practice of regional anaesthesia. In the first applications of ultrasound for regional anaesthesia, the Doppler effect was used to identify arteries, which indirectly enabled the location of nerve structures in their vicinity [2]. In 1989, Ting et al. [3] published a report on the use of two-dimensional ultrasound imaging to visualise targeted nerve structures and to monitor the spread of LAs in real time during the peripheral nerve block. Five years later, Karpal et al. published a similar report [4]. Their findings took regional anaesthesia to the next level — the era of anaesthesia under direct visual control. However, the interpretation of images requires experience, particularly given that the image quality often is not ideal. Moreover, manual dexterity determines the efficacy of ultrasound-guided (US-guided) needle manipulation. Despite its limitations, the method quickly found numerous enthusiasts. The increasing popularity of US-guided regional anaesthesia is reflected in the growing number of publications regarding its use, especially those on PNBs. By the end of the first decade of the 21st century, the ultrasound machine had become a component of standard operating theatre equipment, and it is now difficult to imagine serious considerations on PNBs without referring to ultrasonography as the basic method of nerve location [5].

The 1st Department of Anaesthesiology and Intensive Therapy (DAIT) of the Medical University of Warsaw was one of the first centres in Poland to employ US-guided regional anesthesia on a routine basis. In this department, ultrasonography has been used for PNBs placement since 2007.

The aim of the present study was to evaluate the impact of US guidance on the technique and efficacy of PNBs compared to PNBs performed using traditional nerve localisation methods.

## METHODS

The study design was approved by the Bioethics Committee, Medical University of Warsaw (KBO/14/10). The medical records concerning all PNBs performed by the anaesthetic team of DAIT between 1 January, 2006 and 30 June, 2012 in patients operated on in the Department of Orthopaedics and Trauma were retrospectively analysed. The analysed data included information on the type and access of the PNB, method of nerve location, LA doses, injection method and block-related complications.

The data was statistically analysed using Statistica 10 software for Windows (StatSoft Inc, USA).

## RESULTS

Between 1st January, 2006 and 30th June, 2012, 4,066 PNBs in total were performed. After 1st January, 2007, 921 US-guided blocks were carried out, both combined with NS and without NS use. 24.6% of all PNBs were performed under US guidance. Figure 1 illustrates the increasing incidence of US guidance in the successive years. In the first analysed year, US-guided blocks constituted only 8.6% of all PNBs, whereas they had reached 53.3% by the final year. The increasing percentage of ultrasound-guided blocks may be attributable to the growing number of physicians trained in US operation (Fig. 2), as well as by an expansion in their expertise.

Most PNBs were brachial plexus blocks (95%); 10% of them were PNBs combined with general anaesthesia. Figure 3 presents the distribution of approaches chosen for brachial plexus block depending on the nerve localisation

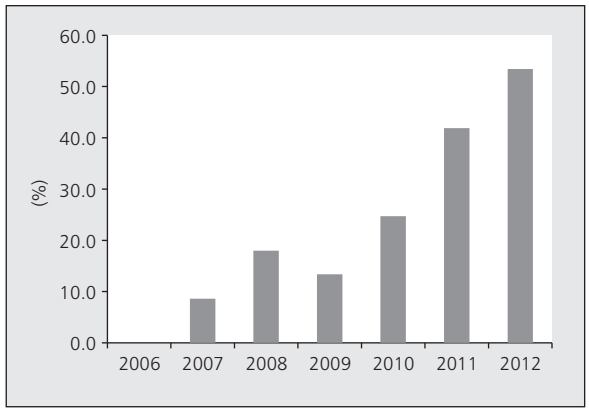


**Figure 1.** Percentage of ultrasound-guided peripheral nerve blocks in the total number of peripheral blocks

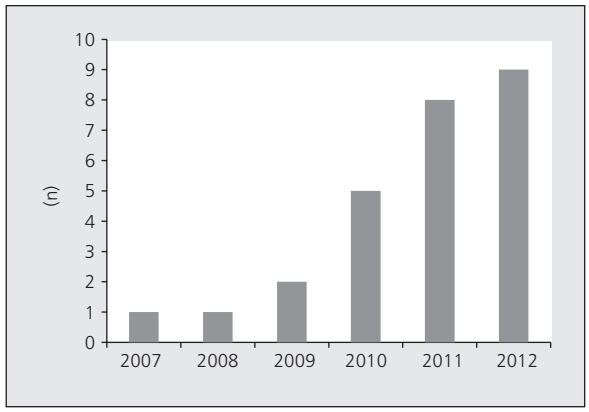


**Figure 2.** Number of anaesthesiologists using ultrasound-guidance

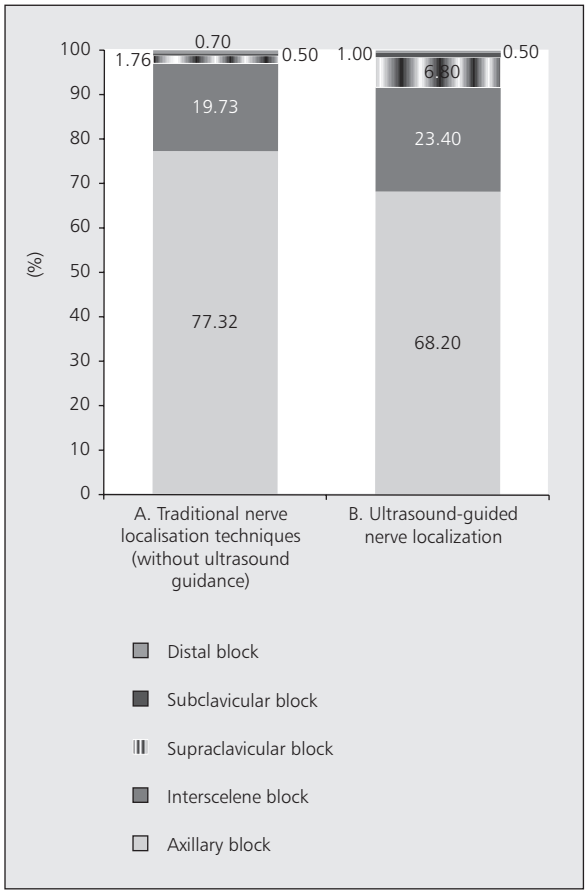


**Figure 3.** Incidences of approaches chosen for brachial blocks depending on the nerve localisation technique

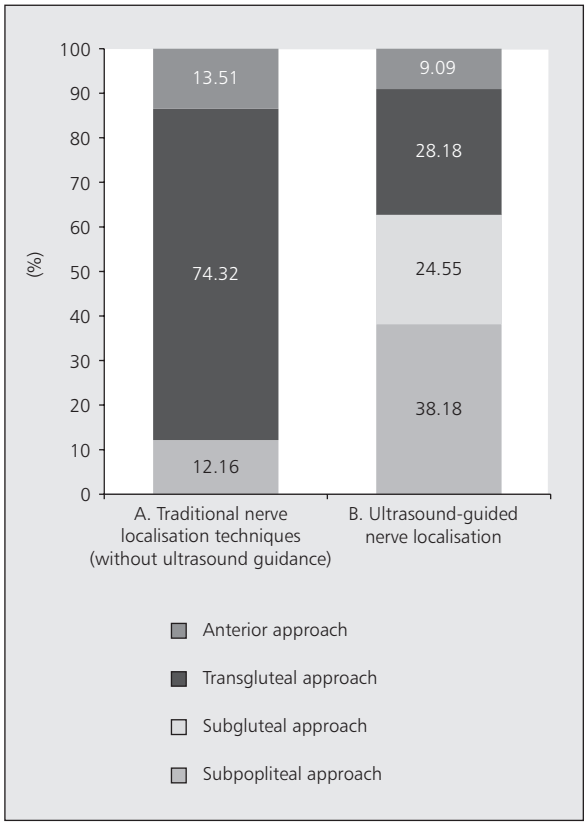


**Figure 4.** Incidences of approaches chosen for sciatic nerve blocks depending on the nerve localisation technique

technique (Fig. 3A — without ultrasound, Fig. 3B — with ultrasound guidance). The most common approaches in both groups were the axillary approach (77.3% and 68.2%, respectively) and the interscalene approach (19.7% and 24.3%, respectively). Other approaches were used rarely. The most prominent discrepancy in frequency of approaches used was noted for the supraclavicular approach (1.76% and 6.8%, respectively).

Lower limb blocks constituted only 5% of all PNBs. Except in a few cases, the objective was to block the femoral and sciatic nerve to provide complete regional analgesia of the lower limb. Femoral nerve blocks were routinely performed at the inguinal ligament level. Approaches used for the sciatic nerve block depended on the type of surgical procedure and the localisation technique used. The frequency of the approaches chosen for sciatic nerve blocks according to the nerve location technique used is presented in Figure 4. With sciatic nerve blocks, the distribution of approaches differs markedly depending on the use of ultrasound guidance or other guidance methods.

Figure 5 illustrates changes in the technique of LA administration during PNBs. In the initial part of the analysed period, the single-injection technique was used in 71% of cases, whereas later 84% of PNBs were performed using the multiple-injection technique. The mean volume of LA used for block placement decreased over the analysed period. In 2006, (before US-guidance introduction) the mean LA volume used was 37 mL and this was reduced to 25–27 mL in the final part of the analysed period (Fig. 6). The mean LA volume used for placement of ultrasound-guided block was 21.83 mL compared to 31.41 mL in traditional blocks ($P < 0.05$) (Fig. 7).

There were no significant differences in the efficacy of PNB according to the identification method applied (Fig. 8).

In the records that were analysed, complications were observed in two cases of interscalene blocks when traditional identification methods were used. In one case, symptoms of cervical epidural anaesthesia developed; in the other case, mild symptoms of LA toxicity were found.

## DISCUSSION

### *BLOCK TECHNIQUE*

Since 2007, the number of ultrasound-guided blocks in the study sample continued to increase. The limited use of US-guided technique in the initial period stemmed from poor knowledge of the ultrasound machine and its operation, limited educational resources and scarcity of teaching centres using this technique. Therefore, the initial period of

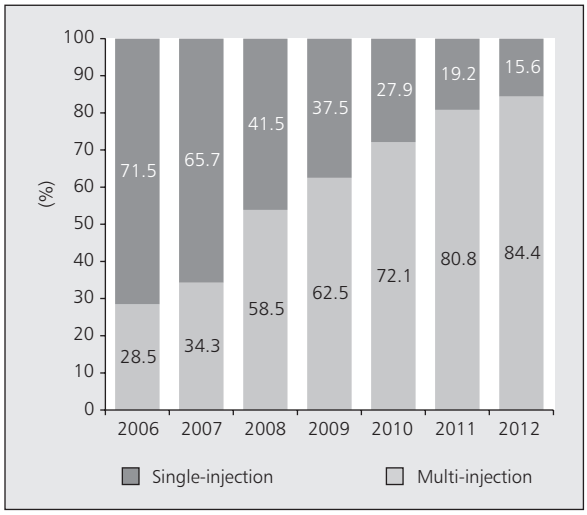


**Figure 5.** Techniques of local anaesthetic administration in peripheral blocks


**Figure 6.** Mean volumes of local anaesthetic used for peripheral block

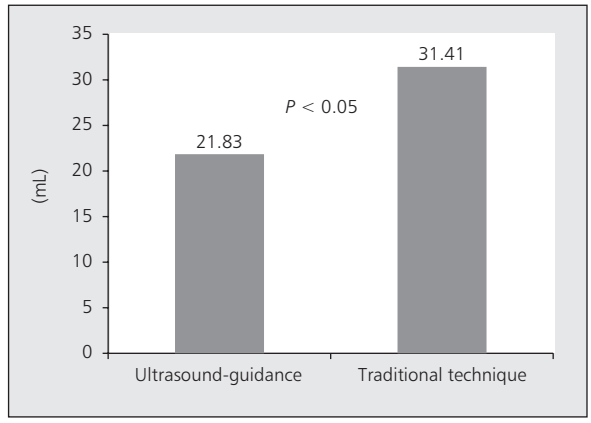


**Figure 7.** Mean volumes of local anaesthetic used for peripheral nerve block depending on the nerve localisation technique

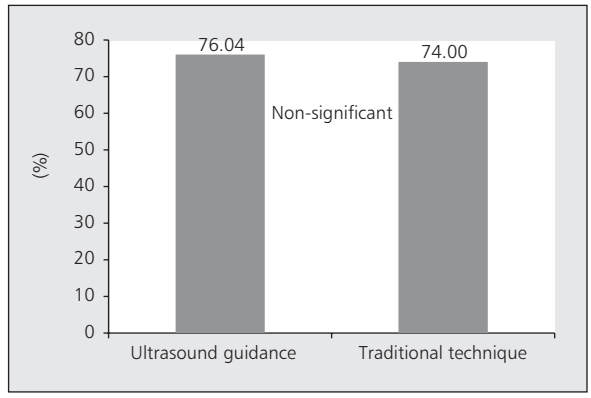


**Figure 8.** Comparison of efficacy of ultrasound-guided peripheral blocks and traditional localisation techniques

applying ultrasound-guided technique may be perceived as the authors having been learning through 'trial and error'.

Prior to the introduction of ultrasound into clinical practice, the most commonly used method of nerve identification in PNBs was the NS technique. The use of other localisation modalities, such as the paresthesia technique or modified methods of NS (i.e. percutaneous electrode guidance (PEG) and sequential electrical nerve stimulation (SENS), was documented only in 2.6% of PNBs performed. Nevertheless, the actual incidence of some of these techniques used as an auxiliary method preceding the main block procedure, especially PEG, could have been higher. Moreover, it should be emphasised that the increasing incidence of US-guided blocks did not translate into a reduction of NS use. The most common localising method was a combined US and NS technique, which was believed to yield significant benefits. The essential advantage of the combined technique is that it facilitates interpretation of the ultrasound image due to the confirmation of nerve identity based on the type of motor response observed. This advantage is particularly important for anaesthetists learning US-guided PNBs. It should be emphasised however, that NS plays a different role when combined with US guidance As ultrasound enables direct visualisation of anatomical structures in the block area, the role of NS as a localising method is markedly decreased. Nevertheless, NS still provides relevant functional information about the needle-to-nerve position and can be used as a way of warning against inadvertent intraneural needle placement [7]. Ultrasound assessment of needle-to-nerve location is highly dependent on image quality and an appropriate level of experience in image interpretation, as well as the manual skills of the person doing the assessing. Therefore, such assessments can often prove difficult [8, 9]. For this reason, NS serves as an important additional method of monitoring the course of the block procedure. When combined with routinely taken precautions, such as aspiration before each injection of the LA, the assessment of resistance during injection and consideration of the symptoms reported by the patient, NS seems to contribute to increased patient safety [10].

Acquired habits and preferences are probably an additional impediment to the combined use of NS and US by

physicians experienced in NS-guided blocks. In such cases, we observe that physicians tend to make decisions concerning the block based on the presence or absence of motor responses instead of the visual control of the procedure. This tendency leads to the 'blind' provision of anaesthesia despite the use of ultrasound, which can result in lower block efficacy. The increased learning curve for the ultrasound-guided technique cannot be excluded from consideration.

In the records that were analysed, the increasing prevalence of US-guided PNBs was associated with increasing numbers of physicians trained to employ the method, as well as their growing expertise. Due to the rising number of physicians trained in US-guided anaesthetic procedures and broad indications for ultrasound use, e.g. vessel cannulation or central blocks placement, there is often a need to use an ultrasound device simultaneously at more than one anaesthesia station. Therefore, the finite number of ultrasound devices available poses an obstacle to the more widespread use of this method.

### *SELECTION OF APPROACH*

Irrespective of the nerve location technique, the most commonly used PNBs were brachial plexus blocks. Lower limb blocks were rarely performed procedures both in terms of absolute values and percentages of all PNBs. The main reason for this seems to be the availability of central neuraxial blocks as an alternative to PNBs in lower limb surgery.

The crucial factors determining the choice of the approach to peripheral block include the type of surgery, institutional management protocols, the availability of equipment, and personal preferences. Therefore, anaesthetic management for similar procedures can markedly differ between individual centres. In DAIT, the axillary approach was the most frequently used approach for brachial plexus block in analysed records. This was related to its technical simplicity, controllability, high efficacy and safety. Moreover, this approach is particularly useful for learning the US-guided technique. In the axillary region, nerves are located superficially and are easy to visualise. The incidence of axillary blocks was comparable irrespective of the nerve localisation technique; a similar relationship was noted for interscalene approaches. The infraclavicular and supraclavicular approaches, which are considered technically more difficult and associated with a risk of puncture of the pleura or infraclavicular vessels, were rarely chosen, especially when traditional localisation techniques were applied. The introduction of ultrasonography into clinical practice has resulted in the increased popularity of these approaches. Both, in particular supraclavicular block, are examples of anaesthetic techniques that became substantially more popular once ultrasonography was introduced to the clinical practice of PNBs. It can be concluded that thanks to the use of ultrasound, these techniques has become percieved as technically easier and safer [11].

Unlike in the brachial plexus blocks, in sciatic nerve blocks the choice of approach varied significantly depending on the localisation technique used. With traditional localisation methods, approximately three quarters of anaesthetic procedures were carried out using the transgluteal approach, whereas in ultrasound-guided cases, the use of transgluteal, subgluteal and popliteal approaches was much more evenly matched. The chief characteristic of the subgluteal approach is the lack of explicit anatomical landmarks that enable easy nerve location. Therefore, in cases of subgluteal approaches, direct ultrasound visualisation of target nerve structures is a prerequisite for successful blocks.

### *LA VOLUME AND ADMINISTRATION TECHNIQUE*

The most common method of LA administration prior to the introduction of ultrasonography to clinical practice was the single injection of a large volume of LA. This method can be traced back to the mid-20$^{th}$ century, when Burnham et al. [12], De Jong et al. [13] and Winnie et al. [14] demonstrated that the deposition in one place of a large volume of LA, sufficient to fill the brachial plexus sheath, induced an effective block. Technical development and the wide use of nerve stimulators enabled the precise location of particular nerves. This resulted in a concept of multiple small injections of LA around targeted nerves. Handoll et al. [15] and Chin et al. [16] showed that the multi-stimulation and multi-injection methods were more effective than the single-injection method and reduced the volume and dose of LA. The introduction of ultrasonography into clinical practice of regional anaesthesia enabled real-time visualisation of needle tip position and LA spread around the nerves and made it possible to block individual nerves. This, in turn, substantially strengthened the significance of the multiple-injection technique in PNBs.

In this study, we have demonstrated a change in the predominant method of LA administration over the analysed time period. Prior to the introduction of ultrasound guidance, the most popular method of LA administration (although not exclusive) was the single-injection technique. In the final year of observation, almost 84% of PNBs were performed using the multiple-injection method. In US-guided blocks, this method was used in 53.4% of cases, which means that the multiple-injection method was increasingly used irrespective of the block guidance method. This trend seems to be attributable to several factors. It had previously been demonstrated that the multiple-injection technique provides higher efficacy compared to the traditional approach [15, 16]. In US-guided blocks, the administration of small increments of LA around the targeted nerves under visual control is a more natural method of block placement

than a single, high volume injection of LA. Thus, ultrasound could have promoted the multi-injection method as such, which in turn might have caused changes in PNB practice resulting in more frequent use of this technique also in non-US-guided PNBs.

The shift from the single injection to the multiple-injection technique as the prevailing method of LA administration was accompanied by a systematic reduction in the mean LA volume used in PNB. This reduction seems to result mainly from the use of ultrasound and real-time visual assessment of LA spread. Direct visual control allows the practitioner to confirm the spread pattern of LA and avoid administration of excessive volume. Moreover, the significance of the multi-injection technique for LA volume reduction should not be neglected, especially in PNBs under traditional localisation methods.

### *EFFICACY OF ANAESTHESIA*

Analysing the efficacy of regional anaesthesia depends on the accepted definition. Two definitions of successful block are commonly used. According to the first, a block is regarded as successful if it covers the area supplied by targeted nerves. The second approach evaluates the 'clinical efficacy' i.e. the block is considered successful if other anaesthetic techniques (general anaesthesia or deep analgosedation) are not required. In the present study, the criterion of 'clinical efficacy' was used, as detailed data on the topographic range of the block was not always available. Our observations failed to demonstrate any effects of ultrasound guidance on block efficacy, which is consistent with the results published by other authors [17].

### *SAFETY*

In the records that were analysed, only two cases of significant peripheral nerve block-related complications were noted. No cases of permanent neurological damage associated with the block were found. The above findings confirm the safety of PNBs, regardless of the nerve localisation method used [18].

## CONCLUSIONS

Ultrasonography is increasingly being used to monitor the course of the block placement procedure in clinical practice of PNBs. It seems that this tendency will continue to grow due to the ever-expanding knowledge of this method, increasing numbers of anaesthesiologists capable of employing it, wider indications for its application and wider availability of ultrasound devices.

Our analysis of the data collected regarding PNBs performed in the university hospital over the period of six years leads us to the following conclusions:

1. US guidance in PNBs facilitates a reduction of LA volume used. Lower LA dose does not impair the quality of anaesthesia.
2. The introduction of ultrasound guidance to clinical practice of PNBs results in changes in the anaesthetic technique. The single-injection technique used earlier is being replaced by the multiple-injection method. The latter is increasingly common also in PNBs without US-guidance.
3. Peripheral nerve blocks are characterised by high safety. Complications associated with their use are extremely rare, regardless of the nerve localisation method applied.
4. PNBs are predominantly used for upper limb analgesia. PNBs for lower limb surgery are rarely placed.
5. Ultrasound guidance contributes to more frequent placement of blocks that previously were performed rarely due to difficult nerve location or the fear of possible.

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