

# **ULTRASOUND GUIDANCE: THE NEW GOLD STANDARD FOR PERIPHERAL NERVE AND PLEXUS ANAESTHESIA?**

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## **Introduction**

Successful peripheral nerve and plexus blockade (PNB) can provide an excellent anaesthetic outcome, either when used alone, or in combination with general anaesthesia. In either setting there is the possibility of prolonged post operative analgesia. When PNB is used as the sole anaesthetic technique, additional advantages may accrue from the avoidance of general anaesthesia complications, such as post-operative nausea and vomiting and cognitive dysfunction. PNB may also result in earlier hospital discharge.<sup>1-3</sup>

However, barriers to the wider use of PNB do exist. Incomplete or unsuccessful blocks remain a particular problem, causing patient discomfort and delays to the OR schedule. Lengthy block performance times and slow block onset may cause late starts, list overruns or patient cancellation. There are concerns about the safety of PNB and in particular the risk of nerve damage which influences patient, surgeon and anaesthetist. In addition, some patients have a negative perception of PNB due to reports of discomfort associated with block performance. PNB techniques are often difficult to master and anaesthetists require regular exposure to appropriate cases to maintain expertise. In absence of such opportunity, anaesthetists will utilise general anaesthesia with opioid based post operative analgesia in preference. Finally, PNB techniques may have additional financial implications; including the cost of equipment, that concern OR managers.

Bearing in mind the limitations of PNB as currently practiced, it is helpful to consider what features an ideal peripheral nerve block technique would offer. The ideal nerve block technique should be:

1. successful;
2. safe (to nerves and other structures);
3. easy to learn and teach;
4. acceptable to patients; and
5. economical.

Four techniques are available to aid the localisation of peripheral nerves for the performance of nerve and plexus anaesthesia and include:

1. landmark based techniques (fascial clicks, arterial puncture);
2. elicitation of paraesthesia from nerve-needle contact;
3. peripheral nerve stimulation; and
4. ultrasound guidance.

Both the literature and prevalent anecdote suggest that most anaesthetists performing PNB currently use peripheral nerve stimulation (PNS). In the last 5 years however, the availability of high resolution portable ultrasound has offered a viable alternative. Proponents of ultrasound guided peripheral nerve blockade (USG) claim it offers several advantages over conventional techniques. These include improved block success, reduced complication rates and easier skill acquisition. Nerve block success may be improved because the anaesthetist can visualise the nerve and thus be confident about its precise location. A clear knowledge of the needle position may reduce the incidence of nerve damage and injury to adjacent structures. In addition, ultrasound imaging may be an easier and safer way to both learn and teach PNB. If clinicians are to change their practice and adopt USG, it seems reasonable to examine the validity of these claims with reference to the current published literature. For the purposes of this review, USG will be compared with the current standard technique of PNS. The other methods will not be discussed further.

## **Block Success**

### *Block success with Peripheral Nerve Stimulation*

Data from large observational studies document 93-98% success rates when skilled operators utilise PNS techniques.<sup>4-7</sup> It is clear, however, that studies of this nature may be subject to significant reporting bias. A more recent study of 1065 consecutive nerve blocks performed in a single Australian institution provides more useful data on current local practice and success rates.<sup>8</sup> Technical problems during block placement occurred in 18% of blocks and included multiple attempts (7%) and equipment failure. Block success (pain score <6 in PACU) was achieved in 85.8% of patients. This is somewhat lower than the success rates reported in the above studies but may reflect the wide range of blocks performed and the variable experience of the anaesthetists involved (the actual number of operators was not reported). It seems likely that very high success rates can be achieved, but primarily by expert practitioners who have performed a large number of the block procedure in question.

#### *Block success with Ultrasound Guidance*

Reports of success with USG first appeared in the literature more than 10 years ago.<sup>9</sup> Initial studies were however quite small. As experience has accumulated with USG, larger series and a wider range of blocks have been reported.<sup>10-15</sup> As with the PNS studies cited above, some measure of reporting bias can be expected. However, one recent study is of particular interest. Dr Sandhu, a pioneer of USG for infraclavicular block,<sup>13</sup> has recently published a series of 1146 cases.<sup>14</sup> In this latter study, success was defined as surgery without additional local anaesthetic supplementation, without additional intraoperative sedation and without general anaesthesia. The success rate in this series exceeded 99%. Whilst the retrospective nature of the study limits its strength, several aspects are interesting. Firstly, a large number of clinicians were involved. The majority of blocks were performed by residents in training with direct supervision by a specialist anaesthetist (only 28 performed by specialists). This is in contrast to many studies utilising PNS where excellent results are only obtained by expert practitioners. Secondly it is now the largest USG series published to date and the success rate is very impressive.

#### *Block success: Direct comparison between Peripheral Nerve Stimulation and Ultrasound Guidance.*

There are several studies that compare block efficacy between PNS and USG. In general the studies are small. Some suggest more rapid block onset with USG, but most fail to show a statistical difference in block success rates.<sup>15-19</sup> In one exception, Chan et al<sup>20</sup> conducted a randomised trial of axillary brachial plexus block in 188 patients. There were 3 groups. The first had a block performed using a PNS technique. The second utilised ultrasound imaging (US). The third group used a combined technique with both US

and NS (USNS). Once the block was performed, patients were observed for 30 minutes by a blinded observer to document block onset. Block success was strictly defined as complete sensory loss in median, ulnar and radial nerve territories at 30 minutes. The requirement for additional local anaesthesia supplementation or conversion to general anaesthesia was also noted. Block success was higher in the ultrasound and ultrasound-nerve simulation groups (83% & 81%) than the nerve stimulation group (63%), ( $p=0.01$  &  $0.03$  respectively). Because of the strict definition of block success, the overall success rate for this series appears low. However in terms of the more clinically relevant endpoint of adequate surgical anaesthesia, 95% of US patients and 92% of USNS patients had adequate blocks. The NS group had adequate surgical anaesthesia in 85% ( $p=0.07$ ).

To summarise, it appears that with adequate experience and training, most anaesthetists will obtain good results with either PNS or USG. There appears to be an advantage with USG in terms on the rapidity of block onset. In addition, it seems that acquisition of expertise may be faster with USG.

## **Safety**

Complications of PNB can be divided into nerve related and non-nerve related. Ligouri<sup>21</sup> describes seven mechanisms by which nerves may be damaged during or following PNB. These include; traumatic nerve damage by needle, ischaemic nerve damage from intraneural injection, nerve compression from haematoma, LA neurotoxicity, surgical injury or positioning related injury, tourniquet damage, and post operative injury related to oedema or poor limb positioning.

### *Nerve related complications of PNB using PNS.*

The rate for nerve injury with a PNS technique varies from 0.004% in the large series by Auroy et al<sup>22</sup> to 14% in the studies by Urban and Borgeat.<sup>23,24</sup> This wide range can probably be explained by the study methodology. Auroy et al conducted a survey of French anaesthesiologists that relied on self-reporting of complications. The high rates documented by Borgeat and Urban were a result of direct patient follow-up for up to 6 months post operatively. Thus in order to interpret the reported safety of a particular technique, it is necessary to know whether there was active patient observation post operatively. Reassuringly, the majority of patients that report nerve related symptoms postoperatively have only minor sensory abnormalities and these usually resolve between one week and one month post operatively.<sup>4,25</sup> Jenkins reports that the risk of permanent nerve damage following PNB is around 1:5000.<sup>26</sup> He notes however that up to 2% of brachial plexus cases report a neuropraxia lasting more than 3 months. This is supported

by Borgeat et al who examined the incidence of nerve injury after interscalene block and reported an 8% incidence of residual nerve symptoms at 1 month, 4% at 3 months but <1% at 6 months.<sup>23</sup>

Watts and Sharma's<sup>8</sup> study of 1065 blocks from a single institution also reported on neurologic outcome. Study methodology has been described in detail above. All patients were reviewed at 7-10 days and then followed prospectively for up to 12 months. Thirteen patients (1.3%) reported post-operative nerve related symptoms. Of these, 8 (0.75%) were considered attributable to PNB. At 6 months post-surgery only 2 (0.22%) had residual symptoms; one resolving at 9 months, the other still apparent. As the authors note, this is not dissimilar to the rate for nerve injury associated with general anaesthesia alone.

Two further studies<sup>27,28</sup> raise questions about how PNS works, and its safety. Both these studies demonstrated nerve-needle contact either by production of paraesthesia, or with US imaging yet subsequent nerve stimulation using currents up to 1mA resulted in low motor response rates. The clear implication is that PNS cannot be relied upon to warn the operator that they are approaching or even in contact with a nerve in all situations. This finding is supported by a report of four cases of permanent loss of cervical spinal cord function following interscalene block performed under general anaesthesia. In three of these cases, the block was performed with PNS.<sup>29</sup>

#### *Nerve related complications of PNB using USG*

USG is in its infancy so not surprisingly the literature on the incidence of nerve related complications is sparse. Of the studies described above, none report any nerve related complications. However, none include patient follow up so this observation is hard to interpret. Clearly it is possible to damage nerves during the performance of an USG block. Schafhalter-Zoppoth et al describe the impalement of a femoral nerve with resulting intraneural injection despite the use of US imaging.<sup>30</sup> Proponents of USG would argue that the technique itself is safe but that anaesthetists must have the correct equipment, be able to use it appropriately, and understand how to image the needle during block performance.

Theoretically, USG offers the potential to reduce nerve damage. With accurate nerve and needle imaging it should be possible to avoid direct needle damage, intraneural injection and compression from haematoma due to vascular puncture. At Auckland City Hospital we are currently performing a prospective audit of the safety of USG. The methodology involves video capture of the block for review in the event of a complication. All patients are being followed up post-operatively to ensure the recording of complications. We have now completed over 200 cases and have yet to document nerve damage related to needle trauma or intraneural injection. Our numbers are small and we continue to enrol patients in the

study. A further large multicentre prospective audit of the safety of peripheral nerve blockade is being conducted by St Vincent's Hospital in Melbourne ([www.regional.anaesthesia.org.au](http://www.regional.anaesthesia.org.au)) Studies of this design may generate the numbers necessary to accurately document the incidence of such complications.

#### *Non nerve complications of PNB*

Other complications of PNB performed using PNS are reported by Jenkins.<sup>26</sup> Minor complications such as vascular puncture and local haematoma are very common. Pneumothorax associated with supraclavicular block occurs in 1:20. More serious complications such as systemic local anaesthetic toxicity occur in 1:1500 and cardiac arrest is reported in 1:10,000. Whilst nerve stimulation can aid identification of peripheral nerves, it is no help in identifying vessels, pleura or any anatomical anomalies that may be present. Ultrasound guidance appears to offer a significant advantage over PNS in this regard and certainly the studies of USG published to date report very low rates for non nerve complications.

#### **Patient acceptance of PNB**

The majority of patients do not experience undue discomfort with PNS techniques. However some patients find the procedure uncomfortable and others may not tolerate it at all (those with fractures or other painful conditions). Another group of patients that present challenges are those with difficult surface anatomy e.g. the morbidly obese. Fanelli et al studied the success and acceptability of a multiple injection technique for in a large series of patients for interscalene, axillary, and sciatic nerve blocks. He found that the technique was poorly tolerated in nearly one third of patients.<sup>5</sup>

Data on patient acceptance of USG is limited. In one study that directly compares patient acceptance of US and PNS for infraclavicular blocks, Marhofer reported that the US technique was better tolerated.<sup>17</sup> Sandhu reported a series of 1146 patients having an infraclavicular block in which 83 patients requiring further surgery chose the same technique again.<sup>14</sup> Our experience of many hundreds of USG blocks is similar; the procedure is very well tolerated and many patients that require further surgery choose the same technique again.

#### **Teaching regional anaesthesia**

One of the factors limiting wider use of PNB is that blocks can be difficult to learn. Anaesthetists sometimes lack adequate exposure to PNB techniques during their training and thus do not develop the skills required to master nerve blockade. Another problem is the loss of expertise seen when clinicians

have insufficient exposure to appropriate cases. Ultrasound seems to offer several advantages over other methods for learning regional anaesthesia. For example, the anatomy observed with the US machine is the actual patient anatomy, not what a textbook says should be there. Learning to operate the US machine and understanding patient sonoanatomy is straight forward and presents NO RISK to the patient. However, one of the more challenging aspects of learning USG is needle imaging. Gel phantoms are available that can be used to simulate passage of a needle into a patient and thereby help to develop these skills prior to contact with a patient. Sites et al formally studied skill acquisition of trainees in anaesthesia using USG.<sup>31</sup> Ten anaesthesia residents were asked to perform a simulated breast cyst aspiration 6 times (chicken breast with implanted olive). Skill acquisition was rapid during the successive procedures. The most common error was failure to image the needle tip adequately at all times prior to advancing the needle.

### **Economic considerations**

Purchasing an US machine is often a difficult process for anaesthetic departments. These items are expensive and managers may need to be convinced that equipment not previously required is now necessary. Fortunately, systems have become smaller and cheaper and there are now several manufacturers producing high quality portable US machines. There is now reasonable evidence to support the requirement for portable US in departments where central venous cannulation is required. If such equipment is to be used for PNB, it is important to obtain a system that offers sufficient image quality: vascular access requires a lower quality image and therefore a cheaper system than that needed for PNB. A recent study by Latzke compares the costs of PNB between PNS and USG.<sup>32</sup> Assumptions were made about success rates and complication rates that favoured the US technique. In addition OR time utilisation was assumed to be superior with US. This meant that even with the additional costs associated with the purchase of an US machine, there was still an economic advantage to using US.

### **Simultaneous use of ultrasound and nerve stimulation**

While this review has focused on a comparison between PNS and USG, it is possible to utilise these techniques together.<sup>33</sup> For a practitioner experienced with PNS, it may be helpful to use US to identify anatomy and assist with locating the correct point for needle insertion. A further modification of the nerve stimulator technique is to use US guidance to place the needle adjacent to the nerve and then turn the PNS on. With this method, the current intensity can be low and then increased, in contrast to the usual practice

of using a high initial current. This approach may be better tolerated by patients. For trainees with limited experience, the combined technique may offer an additional level of safety where needle imaging proves difficult. However, where adequate training is available, the use of PNS may not offer much advantage. It is worth noting that insulated needles are possibly more difficult to visualise than uninsulated ones.

## Conclusion

Ultrasound has already transformed the practice of PNB and its wider availability is likely to ensure even greater use in the future. A recent editorial in the British Journal of Anaesthesia offers a very forthright appraisal of future of USG and suggests that US has already emerged as the gold standard for PNB.<sup>34</sup> If ultrasound does indeed make PNB safer and more successful, our focus may shift away from the choice of PNB technique, and towards a re-evaluation of the risks and benefits of regional versus general anaesthesia.

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