Safe performance of peripheral regional anaesthesia: the significance of ultrasound guidance

Ultrasound guidance has raised regional anaesthesia from an art relying on chiefly morphometric data to a science governed by reproducible and predictable methods. Besides the large number of scientific publications in the field of ultrasound and regional anaesthesia, there are still open questions regarding safety issues. In this issue of *Anaesthesia*, Sermeus et al. [1] present their findings from an investigation into the incidence of nerve puncture and intraneural injection based on various needle-to-nerve approaches. This study provides new findings about safety in ultrasound-guided regional anaesthesia. Whether ultrasound guidance increases safety in regional anaesthesia is of particular interest for those practitioners using such techniques in their daily clinical practice and is the subject of this editorial.

We all know that initial hypes about exciting innovations have a way of rapidly giving way to greater realism. Many physicians have raised specific questions about ultrasound-guided regional anaesthesia, and indeed there are two major questions that remain to be answered: does ultrasound truly provide better success, and does it truly provide better safety, than conventional methods of nerve identification can nowadays offer? On the face of it, it would seem obvious that ultrasound guidance performs better than any techniques relying on nerve localisation, like nerve stimulation or strictly landmark- or paraesthesia-based techniques. After all, a multitude of comparative studies, systematic reviews, and meta-analyses have demonstrated faster onset times, longer block durations, better predictability of block success, and reduced needs for supplemental analgesia [2–5]. Nevertheless, a study offering ultimate proof to settle this issue of superiority once and for all has yet to be published. Assuming that the appropriate measure of superiority of a nerve block is improved success and better safety, the question arises what kind of study design would be appropriate to verify such superiority? Success would be the sum of various parameters like sensory and motor onset time, duration of sensory and motor blockade, or number of failed blocks. In fact, there is no shortage of available studies on all these aspects of successful blockade, but the chances are slim that a definitive study providing ultimate proof of one specific technique being superior to the others is ever going to be published. What makes this outlook seem unrealistic is that, in the meantime, every institution favours one specific technique (mainly ultrasound or nerve stimulation, maybe paraesthesia-based identification of nerves in some cases), which implies that no single institution can possibly offer the same level of expertise for two different techniques. Thus, any multi-centre study design would involve an inter-institutional bias precluding a valid comparison of methods, and would likely end up showcasing competing philosophies rather than straightforward science.

As to the safety offered by specific methods of peripheral nerve blockade, the cadaveric study by Sermeus et al. compared a tangential with a direct needle-to-nerve approach [1]. The gist of their data is that the tangential approach involved fewer ‘intraneuronal’ injections than the direct approach (12% vs. 58%; p < 0.001). The authors also used additional injections with ink for histological analysis to see whether these intraneuronal injections were actually infrasacular injections. The fact that they
observed no such intrafascicular events is a notable result that merits discussion in greater detail.

First of all, some disambiguation is required as to the microanatomy of a peripheral nerve. Most of the pertinent reports in the literature use the term ‘intra-neuronal’ injection when this designation clearly is not sufficiently accurate. Remarkably, the first regional blocks, performed by the US surgeon William Halsted and his Irish colleague Richard John Hall, were also described as ‘intra-neuronal injection’ [6], despite the fact that they could not detect the exact site of drug administration. Nowadays, anatomical details must be described more precisely. Individual nerve fascicles are enclosed by perineurium, and groups of these fascicles by epineurium, with the subepineurial fascicles being separated by subepineurial tissue. The actual axons are located inside the fascicles. Thus, any peripheral nerve will consist of several tissue layers, but inflicting damage to a nerve is contingent on axons getting destroyed, considering that electrical impulses are conducted exclusively by axons. These axons are logically much thinner than the calibre of the nerve fascicles, which may vary between 0.5 μm (0.0005 mm) and 20 μm (0.02 mm). Now consider that a 15 MHz linear ultrasound probe will, under ideal conditions, offer a lateral resolution of 0.2 mm at best. From this, it clearly follows that identifying nerve fascicles by ultrasound is not an option, given that the lateral and axial resolution (both planes are required to discriminate adjacent points) offered by the high-frequency probes used for nerve blocks does not exceed 15–18 MHz.

Even (currently experimental) probes operating at higher frequencies (up to 45 MHz) will max out at 100 μm (0.1 mm) of lateral resolution and, for that matter, can only penetrate a shallow distance into tissues, thus limiting their application in the daily clinical practice of regional anaesthesia [7]. To summarise, ultrasound is capable of demonstrating subepineural injection but cannot provide information on whether an injection has stopped in the subepineurial tissue or has actually penetrated the intrafascicular space. We presume that the former scenario must apply to most reported ‘intra-neuronal’ injections. Otherwise, Bigeleisen and colleagues, who recommend intraneuronal injection, would be guilty of numerous permanent nerve injuries, whereas their studies revealed that these injections rarely eventuated in nerve damage [8, 9]. Subepineural injection causes the epineurium to rupture, thereby preventing pressure-related damage to axons. In addition, it would be an error to suppose that nerve stimulation prevents subepineurial injection [10, 11].

Nerve injury

Now, while this might lead us to believe that nerves are sturdy enough to resist any damage resulting from nerve blocks, evidence to the contrary has recently been presented by Kirchmair et al. [12]. They observed that one isolated mechanical nerve injury, like the trauma inflicted by contact with a needle, can be enough to result in myelin disruption or axon loss associated with a significant decline in compound muscle action potential amplitudes. While we cannot judge the practical implications of this finding in the daily clinical practice of peripheral regional anaesthesia, we do learn from it that needle-to-nerve contact should be avoided whenever possible. Against this background, the case that Sermeus et al. are making for a more tangential needle-to-nerve approach to minimise the risk of direct contact is highly relevant. Still, one should bear in mind that both groups’ findings were derived from a cadaveric model, which is not a viable basis for wide-ranging conclusions about nerve injuries caused by needles in vivo. Obviously, these studies did not look into neuronal reactions like secondary damage, repair mechanisms, or neuroplasticity.

We can only speculate about the true rate of permanent nerve injury after peripheral regional anaesthesia. Most complications related to nerve blockade are not caused by the block procedure as such. While some reports have proposed a complication rate of up to 14% [13], it should be considered that nerve injuries are caused not least by coincidental factors such as patient positioning during surgery, trauma induced directly by the surgeon, tourniquets, or postoperative swelling [14]. More reliable proportions in the order of 0.03% are documented for the incidence of nerve damage truly ascribable to intrafascicular causes during nerve blocks [15]. As noted above, constraints of the physics involved make it
impossible for ultrasound to diagnose and prevent the complication of intrafascicular injection. It is simply not possible to compare methods of nerve identification – and notably between ultrasound and nerve stimulation as the two most important methods – in order to find out how they affect the incidence of permanent nerve injuries after regional blocks. Given a standard α- and β-error and assuming a 0.03% incidence of nerve injuries, any demonstration that one technique reduces this incidence by half would require 313,882 patients to be enrolled in a study. However, if we consider block failure as a complication – and this is in fact the complication with a significantly higher incidence as compared to nerve injury – we should focus with our studies on block success. If we are able to further optimise our ultrasound-guided regional anaesthesia block techniques we can avoid the main complication: block failure!

With no hard evidence to lean on, we have to search for compromises. Experimental studies have shown that direct needle-to-nerve contact should be avoided [11, 12] and that a tangential end-position of the needle is safer than a direct approach [1]. High-resolution ultrasound with clinically useful frequencies of approximately 15 MHz can offer excellent information about macroscopic neuronal structures, about the needle, and about neighbouring muscles, vessels, tendons, or bones. Hence the policy suggested by Sermeus et al. to go for a needle position tangential to the nerve structure without making direct contact should go a long way towards avoiding nerve injuries. This statement holds true of single nerve blocks, ideally with ultrasonographic visibility of the paraneural fascial sheath. A strictly tangential approach to neuronal structures more complex than that, brachial plexus blockade via a supraclavicular approach being a typical example, will not be possible. Whether some approaches may carry a higher risk of prolonged or permanent nerve injuries than others remains to be demonstrated, but studies to this effect will remain largely confined to case reports or case series.

Just like any medical speciality, regional anaesthesia will always retain a fair amount of user dependence. The human factor will (thankfully!) always remain part of the equation. No amount of evidence in the literature can change the fact that each and every nerve block will continue to rely heavily on well-designed guidelines, training methods, reporting of critical incidents, individual hand skills, and intuition. Experience, a high case-load, and continuous training are required for correct probe handling, optimal imaging, interpretation of artefacts, manipulation of needles, distribution of local anaesthetic, and spatial visualisation skills. The literature does provide us with the theoretical background that we require in clinical practice, but it is our responsibility as humans to bring this background to life. Ultrasound is just one, albeit an important, factor towards making peripheral regional anaesthesia a safer method. It will take clinical research into the neurotoxicity of local anaesthetics and epidemiological studies to improve our understanding of the complications involved in nerve blocks. Sermeus et al. have added one more building block to the scientific edifice of anaesthetic techniques, and they provide information of consequence to our daily clinical practice.

Acknowledgements
PM has received travel reimbursement from Safersonic Inc. and is member of the editorial boards of the British Journal of Anaesthesia and Pediatric Anesthesia. No external funding or other competing interests declared.

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Keywords: anaesthesia: conduction; nerve block; nerve tissue; peripheral nerve injury; ultrasound: intervention

References
A new regional anaesthetic block technique is described in this issue of *Anaesthesia* by Chin et al. whereby local anaesthetic is injected within a plane beneath the erector spinae muscle to achieve analgesia for abdominal surgery [1]. A review of the sono-anatomy presented suggests that this is a simple block to perform, and is probably safe. But is this investigation of yet another new block conducted merely for discovery’s sake, or is the erector spinae plane (ESP) block addressing a problem that is crying out for a solution?

### Problems

To understand the value of new techniques, we need to explore how they refine current practice. Improved standards in peri-operative care can be attributed to a wide range of changes to clinical conventions. One of the most significant breakthroughs in recent times has been the introduction and global uptake of enhanced recovery after surgery (ERAS) [2], particularly in the cohort of patients having abdominal surgery. Early pre-operative assessment, screening, education and optimisation complements peri-operative measures such as carbohydrate loading, antibiotic prophylaxis, thromboprophylaxis, thermoregulation, goal-directed fluid therapy and multimodal analgesia [3]. There remains limited high-quality evidence regarding the value of each element [4], contributing to heterogeneity in the precise components of existing protocols. However, the overarching concept of a bundle of peri-operative interventions to improve outcomes can be both cost-effective and globally applied [5, 6].

The responsibility thus falls to the anaesthetist to modify management to increase both quality and outcomes of peri-operative care. Multimodal analgesia is critical both to ERAS [2] and to achieve the target of DREAMing (DRinking, EAting and Mobilising) [7]. Regional anaesthesia complements and enhances multimodal analgesia for abdominal

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*This editorial accompanies an article by Chin et al., Anaesthesia 2017; 72: 452–60.*
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