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Original Contribution

Editorial: Safety monitoring for peripheral nerve blocks – Is there a state-of-the-art standard to avoid nerve injuries?

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HIGHLIGHTS

- Since there is only a low level of evidence, it is difficult to agree on state-of-the-art standards or to provide recommendations and guidelines.
- The value of combining several monitoring devices for dual or triple guidance must be challenged.
- The principle of fascial plane blocks is suitable to avoid traumatic needle-to-nerve contact. However, local toxicity must be regarded as a possible mechanism for nerve injuries.
- Block procedures might be conducted during sedation or general anesthesia when considering the individual patients' clinical situations and the expertise of the anesthesiologist.
- The quality of ultrasound equipment and education provided by the corresponding anesthesia department is highly relevant

The introduction of ultrasound guidance has facilitated regional anesthesia techniques and led to a significant increase in the use of peripheral nerve blocks in today's clinical practice. As an alternative to general anesthesia peripheral nerve blocks are particularly useful for patients with pulmonary impairment or unstable cardiovascular conditions. As part of a multimodal treatment, peripheral nerve blocks can decrease postoperative pain, reduce opioid related side effects and accelerate postoperative recovery [1]. Unfortunately, for most surgical procedures a beneficial effect on persistent postsurgical pain could not be demonstrated [2]. On the other hand, neurological symptoms as a side effect due to peripheral nerve blocks are well known. Temporary nerve impairment can be identified in up to 3% of patients, the incidence of persistent neuropathies after peripheral nerve blocks is about 1–4 in 10.0000 patients [3,4]. The apparently low incidence of nerve injuries might be a result of underreporting due to inappropriate documentation, follow up, or legal implications [5]. The occurrence of permanent nerve injuries, however, can have devastating implications for a patient. The possible consequences of a nerve damage are sensory and motor deficits, and chronic pain [3].

Compared with traditional methods for nerve localization, ultrasound has improved outcomes and safety parameters for peripheral nerve blocks procedures – i.e. success of nerve block, occurrence of local anesthetic systemic toxicity [6]. The use of US guidance may also be associated with a lower incidence of postoperative nerve injury [7]. Yet, nerve injuries are still representing a threat when performing regional anesthesia. In this editorial, we want to review techniques and proceedings that can be used to improve safety with regard to neurological complications after peripheral nerve block procedures.

1. Additional guidance methods

Electrical nerve stimulation can be combined with ultrasound guidance to confirm location of target nerves by eliciting a neuromuscular response. This can be particularly of value on the hands of less expert anesthetists, challenging patients with suboptimal anatomy, or deep blocks with difficult ultrasound interpretation are performed. On the other hand, a combination of ultrasound guidance with electrical nerve stimulation has been advocated to avoid intraneural needle placement and traumatic needle-to-nerve contact. For the concept of “dual guidance” a nerve stimulator is set to a relatively low current level. When a specific neuromuscular response is observed, the needle should not be advanced any further towards the target nerve. Neuromuscular responses with a low current threshold may require the withdrawal and repositioning of the needle. However, the concept of dual guidance has considerable limitations. Even though a current of 0.5 mA (with 0.1 ms impulse duration) is frequently advocated, there is very little evidence

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for this recommendation. The ease to obtain a neuromuscular response, depends on many factors, such as distribution of sensory and motor fibers within a nerve, the conductivity of the surrounding tissue, or the type of block needle that is used for a peripheral nerve block procedure [8]. Premorbidities like diabetes mellitus, neurological diseases or neuropathies can interfere with the effect of nerve stimulation and eventually increase current thresholds [9]. Furthermore, nerve stimulation is only reliably as long as a local anesthetic injection has not been carried out [10]. There are no clinical trials to date that have shown that the incidence of nerve injuries can be reduced by using dual guidance.

Dual guidance can even be expanded to a triple monitoring when a commercially available pressure monitor is used as an additional safety device. The concept of pressure monitoring is based on the assumption that intraneural injection within the fascicles (the bundles of axons that are surrounded by perineurium) of peripheral nerves is combined with high injection pressure that will lead to nerve injuries [11]. In an experimental setting a 25-gauge needle could be placed in the fascicles of sciatic nerves in dogs by using light microscopy [11]. However, needle placement within the fascicles must be considered as very unlikely in a clinical situation. The dimensions of a 21-gauge needle that is commonly used for peripheral nerve blocks is greater than the diameter of most fascicles in human peripheral nerves. On the contrary, many illustrations used in textbooks or in advertisements for commercially available pressure monitors falsely give the impression that the size of the fascicles exceed the size of an injection needle by a multiple. Pressure monitoring is also unlikely to prevent intra-epineural injections (within the epineurium of a peripheral nerve) as shown in two recent studies [12,13]. Yet, the most important argument questioning the value of pressure monitoring is, once more, the lack of controlled studies that can prove a protective effect of the method.

It should be considered that the combination of several monitoring devices with their described limitations, do not necessarily contribute to an improved safety. False positive responses from electrical nerve stimulation or pressure monitoring might lead to unnecessary and repetitive needle replacement that will increase the risk of traumatic nerve damage and other vulnerable structures. On the other hand, ultrasound image quality, operator experience and educational standards have considerably improved during the recent years. Many colleagues might therefore prefer a single guidance approach using only ultrasound to perform block procedures. It must be emphasized that ultrasound machines used for regional anesthesia should correspond to the currently available technical standard. In the event of a claim related to a nerve injury, the question whether dual guidance was be applied should be less relevant than the standard and quality of ultrasound equipment and education provided by the corresponding anesthesia department.

2. State of consciousness

A controversial question is whether patients should be conscious, or whether it is acceptable to perform peripheral nerve blocks in sedated or anesthetized patients. In contrast to the adult population, performing blocks under general anesthesia is standard practice in pediatric patients [14]. It is believed that general anesthesia and deep sedation contribute to a controlled working situation, to avoid damage caused by uncontrolled movements and to prevent fear and panic among pediatric patients. The reason why adult patient should be awake during block procedures is the assumption that paresthesia and pain during injection can be a warning sign of impending nerve injury. This idea is supported by case reports and non-randomized studies in which patients with nerve impairment reported pain during the block procedure [15,16]. It is uncertain whether a nerve injury has already taken place when pain occurs, or whether it can still be averted by withdrawal of the injection needle. Nerve damages without painful sensation during block performance have also been frequently documented [17]. An increased risk of nerve damage due to block performance under general anesthesia has not been shown in studies so far. As for the pediatric population, there are situations where deep sedation or anesthesia in adult patients is more appropriate compared to a waking state or low sedation [18].

3. Needle-to-nerve distance

Obviously, the most effective strategy to avoid traumatic injuries is to keep the needle in a safe distance to the nerve. Due to the availability of ultrasound guidance, numerous fascia blockades have achieved great popularity. For these blocks, a high injection volume is used to cover the target nerves with local anesthetics in remote position within a defined anatomical compartment. Even though fascial plane blocks can provide appropriate postoperative pain relief as part of a multimodal treatment, they are usually not suitable as a sole anesthesia technique during a surgical procedure. Due to the large distance between needle and target nerve, traumatic nerve injurie are rather unlikely when fascial plane blocks are performed.

In contrast to a fascial plane block, the injection needle is placed in close proximity to the target nerves when performing classical perineural blocks. When conducting ultrasound-guided perineural blocks, many anesthesiologists aim for low injection volumes. Low drug doses may reduce the risk of systemic toxicity. For a successful low volume block the needle tip must be placed very close to the nerves and multiple injections are often necessary. Such rather aggressive needling procedures are associated with an increased risk for traumatic nerve injury. To reduce the risk of needle trauma, the principle of a compartment block can be applied for many perineural blockades. Sufficient spread to the femoral nerve, for instance, can be obtained when the needle is placed under the fascia iliaca some centimeters away from the nerve [19]. When positioning the needle within the neurovascular sheet of the infraclavicular brachial plexus one larger injection volume at one injection site could be applied as an alternative to three or more needle positions. Accordingly, we should consider to rather minimize the number of needle positions and increase the local anesthetic volume instead of minimizing the injection volume at several needle tip positions [20].

4. Local toxicity

Discussions about nerve injuries often focus on a mechanical needle trauma during the block procedure. It should not be ignored that local anesthetics agents (with and without adjuvant drugs) cause local toxicity that may lead to nerve injuries. Local toxicity is thought to be time-, concentration-, and drug-dependent [21]. There has been increasing awareness among clinicians in the recent years, not to use unnecessarily high concentrations. Further studies that focus on local anesthetic toxicity and block related nerve injuries are warranted.

As for each medical procedures there will always remain a risk of side effects associated with peripheral nerve blocks. A cautious attitude towards an invasive method and a reasonable risk-benefit ratio should inherently be the basis for the indication of regional anesthesia techniques.

In conclusion, since there is only a low level of evidence, it is difficult to agree on state-of-the-art standards or to provide recommendations and guidelines for the application of peripheral nerve blocks that may reduce the risk of nerve damage. The value of combining several monitoring devices for dual or triple guidance should be challenged. Block procedures might be conducted during sedation or general anesthesia when considering the individual patients' clinical situations and the expertise of the anesthesiologist. The principle of fascial plane blocks is suitable to avoid traumatic needle-to-nerve contact. However, local toxicity must be regarded as a possible mechanism for nerve injuries. Moreover, a reasonable risk-benefit ratio should be in the first place when treating patients with regional anesthesia techniques. Finally, in the event of nerve damage due to a peripheral nerve block, claims should focus on the anesthesiologist's expertise including knowledge, experience and manual skills instead of a questionable dual or triple

monitoring during needle guidance.

CRediT authorship contribution statement

Axel R. Sauter: Conceptualization, Writing – original draft. **Thorsten Steinfeldt:** Conceptualization, Writing – original draft.

Declaration of competing interest

The authors, Axel R Sauter and Thorsten Steinfeldt, declare that they have no no competing interests.

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