Photoacoustic imaging and spectroscopy for monitoring perfusion and oxygenation in man – effects of epinephrine in local anesthetics

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Lidocaine with epinephrine is used worldwide, to reduce bleeding and prolong local anesthesia by inducing vasoconstriction. Pain on injection can be reduced by buffering the solution, but unfortunately, high-concentration lidocaine with epinephrine (>10 mg/ml + >10 μg/ml) cannot be buffered due to precipitation. Injection of local anesthetic containing epinephrine can also be used as a model to evaluate imaging techniques measuring perfusion, oxygenation and metabolism in the tissue. Many existing techniques have drawbacks such as motion artifacts constituting a need to find new non-invasive methods.

The aim of the first study was to investigate whether a local anesthetic with a high concentration of lidocaine with epinephrine (20 mg/ml + 12.5μg/ml) for longer operations is justified, or whether buffered lidocaine, with a lower concentration of epinephrine (10 mg/ml + 5μg/ml), is just as effective. The anesthetic effect was compared to that of only lidocaine (20 mg/ml). The three preparations of local anesthetics were injected subcutaneously in the forearm of twelve subjects. Pain on injection, onset and duration of anesthesia was rated using a numerical rating scale. Buffered lidocaine with epinephrine was the least painful compared to non-buffered lidocaine and lidocaine with epinephrine (p<0.05). The duration of anesthesia was much longer for the injections containing epinephrine (5.6 and 6.6 hours) than for lidocaine alone (1.3 hours) (p < 0.01). Taken together, the buffered preparation seems to have the same duration as the unbuffered preparations at higher concentrations, but causes less pain on injection.

The aim of the second study was to investigate the possibility of using an in-house novel technique of extended-wavelength diffuse reflectance spectroscopy (EW-DRS) to measure perfusion after a subcutaneous injection of lidocaine with epinephrine in nine subjects. EW-DRS detected a change in the wavelength intervals 510 to 610 nm, known to change upon deoxygenation of hemoglobin, and stable hypoperfusion was found at 2.6 min. The broad spectrum can provide detailed information on the molecular changes taking place in the tissue.

The aim of the third study assess the feasibility of photoacoustic imaging (PAI) to monitor oxygen saturation (sO₂). The results were compared to that of a commercially available DRS (moorVMS-OXY™, Moor Instruments, Devon, UK). Local anesthetic containing epinephrine was injected superficially in the dermis of the forearm skin in seven subjects. PAI showed a decrease in sO₂, restricted to the superficial vascular plexus in the dermis, while blood flow remained unaffected in deeper skin layers. In contrast, DRS showed a paradoxical increase in sO₂ upon the administration of epinephrine, which could be the result of the so-called window effect in which vasoconstriction causes blanching of the skin, changing its optical properties.

In conclusion, a buffered local anesthetic causes less pain on injection with a satisfactory duration, indicating that such preparations could be used for surgical procedures lasting up to 5 hours. EW-DRS is a simple and portable technique for monitoring perfusion, serving a local measurement of the tissue. The more advanced technique, PAI, provides spatial resolution and appears to be a promising technique for monitoring sO₂ in e.g. reconstructive surgery, diabetic ulcers and burn wounds in the future.
