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RECENT ADVANCES OF LOCAL ANAESTHESIA IN DENTISTRY: A REVIEW

Dental Science

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ABSTRACT

Over the past century, there is perhaps no greater contribution to the practice of clinical dentistry than the development and application of local anaesthesia. What were once considered painful procedures have now been made routine by the deposition and action of local anaesthetics. This article will serve as a review of basic pharmacological principles of local anaesthesia, subsequent sequelae that can arise from their use, considerations when using local anaesthetics, and recent advances in the delivery of local anaesthetics.

KEYWORDS

Local Anaesthetics, Pharmacology, Adverse Reaction, Drug Interaction, Mechanism Of Action

INTRODUCTION

An average dentist will administer over 1,500 cartridges of dental local anaesthetic a year.[1] As such, anyone administering this drug should be intimately familiar with what the drug does to the body, as well as what the body does to that drug. This article will serve as a review of the pharmacokinetics and pharmacodynamics of local anaesthetics, possible consequences and adverse events from their use, and emerging technologies pertaining to the use of local anaesthetics.

PHARMACOLOGY

Chemical Structure

Modern local anaesthetics are typically differentiated based on their chemical structure, specifically the linkage (an amide versus an ester linkage) between common elements of the compound. The majority of commonly used dental local anaesthetics fall into the amide category (lidocaine, mepivacaine, bupivacaine, prilocaine), though there are some amide-type local anaesthetics that also contain an additional ester linkage (articaine). While both types of local anaesthetics have the same mechanism of action, they differ slightly in their metabolism as described below. It is rare in dentistry that ester-type anaesthetics are used for local anaesthesia purposes, though these types of anaesthetics are used more commonly for topicalisation prior to injection to reduce discomfort associated with mucosal needle puncture.

Mechanism Of Action

Local anaesthetics all act in the same manner – they bind to cellular sodium channels and inhibit the influx of sodium into the cell which prevents cell depolarisation and subsequent transmission of the previously propagating action potential.[2] This is beneficial in that the action potential of a painful stimulus, such as drilling into the dentin of a tooth, can be stopped from reaching the higher processing centres of the brain and otherwise painful procedures can be completed with relative patient comfort.

Duration Of Action

The duration of action of a local anaesthetic is contingent on two factors: the protein binding and redistribution of the local anaesthetic. Protein binding of the local anaesthetic is an inherent drug characteristic – the more protein-bound a drug is, the longer the duration of action.[3] Duration of action on dental pulp and soft tissues is contingent almost completely on diffusion away from the site of action of the local anaesthetic. If an area is more vascular, the faster the drug will be absorbed into systemic circulation and away from the target tissue.

Metabolism And Elimination

Amide-type local anaesthetics are biotransformed into water-soluble metabolites in the liver by hepatic microsomal enzymes and subsequently excreted by the kidney.[4] Articaine is primarily metabolised via its ester linkage by plasma esterases in the blood.

Adverse Events

Systemic toxicity
Allergy
Psychogenic reactions
Lip/cheek/tongue biting
Trismus
Intravascular injections
Haematoma
Ocular complications
Non-surgical paraesthesia
Methaemoglobinemia

Considerations

Anatomic Considerations Leading To Local Anaesthesia Failure

While supraperiosteal injections are generally sufficient to achieve pulpal anaesthesia for maxillary dentition, these types of injections are significantly less successful for mandibular teeth due to the thickness of the bone cortex. As such, deposition of local anaesthetic adjacent to the inferior alveolar nerve (IAN) must be carried out via one of several approaches, all of which have varying rates of success[5] and none of which are able to accomplish nerve blockage 100% of the time.[6] This can be attributed to various hard and soft tissue characteristics creating uncertainty about the position of the needle tip relative to the IAN, fascial linings acting as a potential barrier to the diffusion of local anaesthetic solution, and the sphenomandibular ligament possibly impeding diffusion of local anaesthetic to the IAN (likely because the needle tip was too medial to the mandibular foramen).[7] Accessory innervation from the mylohyoid nerve, the long buccal nerve, the greater auricular nerve, and even a bifid IAN can also carry additional sensory fibres to mandibular dentition. Given the above information, all injections should be performed with prior examination of the patients' anatomical features to permit minor alterations to technique as necessary in order to maximise chances of success of a nerve blockade.

Inflamed Dental Pulps

As carious lesions increase in size and proximity to pulpal tissue, various biologic markers are produced and subsequent inflammatory mediators are recruited to the site. This inflammation creates a localised area of inflammatory acidosis where the lowered pH value inhibits the action of local anaesthetics due to the altered interaction with components of the liposomes.[8] Additionally, various isoforms of tetrodotoxin-resistant sodium channels (i.e. sodium channels on which lidocaine has a reduced antinociceptive effect) are recruited in the inflammatory state.[9] This combination of factors can make reliable and profound anaesthesia very difficult to achieve, and practitioners should be prepared to administer adjunctive techniques such as intraosseous or periodontal ligament injections in order to provide a comfortable experience for their patients.

Pregnancy

At this time, only lidocaine and prilocaine have an FDA foetal risk classification indicating no risk of teratogenic effects based on the results of human and animal studies. Other commonly used local anaesthetics (bupivacaine, articaine, mepivacaine) have an FDA foetal risk classification indicating that teratogenic risk cannot be eliminated on the basis of human and animal studies.[10] The first trimester of pregnancy poses the highest threat for teratogenicity and so only emergent dental work should be completed during this trimester. It is currently believed that the second trimester poses the lowest risk of foetal harm and local anaesthesia use should in theory be safe.[11] While it is possible to complete elective dental treatment during the third trimester of pregnancy, there is a higher risk of aortocaval compression and increased conduction blockade. If local anaesthesia is to be administered in the third trimester, lower doses should be used.

Elderly

Current demographic data show that the North American population is aging, and projections suggest that the percentage of older people will continue to increase. In those of advanced age, the pharmacokinetics and pharmacodynamics of many drugs are altered.[12] No significant differences in the response of the elderly to local anaesthetics are expected. However, as aging is accompanied by decreased liver and kidney function, doses below the maximum are recommended.[12] Also, geriatric patients commonly have cardiovascular disease and, thus, the dose of epinephrine contained in anaesthetics should be limited to a maximum of 0.04 mg .[12] Even without a history of overt cardiovascular disease, it is prudent to minimise the use of epinephrine in elderly patients simply because of the expected effect of aging on the heart. Monitoring blood pressure and heart rate is advised when considering multiple administrations of epinephrine-containing local anaesthetic.

Children

Children are at higher risk for soft tissue injury due to a relative lack of awareness after local anaesthetic administration. Children are at a higher risk for local anaesthetic systemic toxicity because they weigh significantly less than an adult patient so their absolute threshold for local anaesthesia deposition is much lower than that of adults.[13] Practitioners should also be aware of patient and personal safety when delivering local anaesthetic to a pre-cooperative or anxious child as needle-stick injury may be more likely given a mobile target for local anaesthesia deposition.

Patients On Anticoagulants

It is currently understood that patients within therapeutic international normalised ratio (INR) ranges can receive local anaesthetic nerve blocks without cessation of the anticoagulant beforehand. Even if a haematoma does occur, local haemostatic measures are generally sufficient to produce haemostasis.

Advances

Computer-controlled Local Anaesthetic Delivery

There are now several electronic devices on the market that aid in the delivery of local anaesthesia, specifically with digital controls that can be manipulated to aid in aspiration and continuous delivery of local anaesthetic solution.[14] Many microprocessor-aided local anaesthesia devices will monitor the counter pressure exerted by the tissues into which the local anaesthetic is being injected and vary the rate of deposition of injectable accordingly.[15] In addition to assuming a less threatening appearance than a traditional syringe and needle armamentarium, these computer-controlled devices will ensure both appropriate aspiration and duration of delivery of the local anaesthesia which may reduce injection pain.

Phentolamine Mesylate

Most local anaesthetic cartridges deposited worldwide contain epinephrine, so for patients at higher risk of traumatic injury to soft tissues or simply patients who wish to have their blockade reversed more quickly, phentolamine mesylate is a vasodilator that when deposited in a similar location to the original epinephrine-containing local anaesthetic solution can overwhelm the previous vasoconstriction and aid in the redistribution (and the clinical offset) of the local anaesthetic. Recent studies suggest that it may have particular use in children in providing a more rapid recovery of lip sensation which may decrease the incidence of soft tissue trauma associated with local anaesthetic delivery in this age group.[16]

Buffered Local Anaesthetics

It is believed that an increased pH of a solution being deposited could decrease the amount of discomfort associated with injections and increase the speed of onset of nerve blockade. Current studies show that the above claims above are increasingly likely to be true and dental manufacturing companies are creating devices that alkanise, that is increase the pH of, local anaesthetic solutions prior to dental injection. It should be noted that a recent meta-analysis shows that buffered local anaesthetics have 2.23 times greater likelihood of achieving profound anaesthesia in pulpally involved teeth.[17]

Inhaled Local Anaesthetics

A combination of local anaesthetics (tetracaine) and nasal decongestants (oxymetazoline) is being used to anaesthetise maxillary anterior teeth. This combination of drugs may demonstrate less successful pulpal anaesthesia and more adverse events compared to traditionally deposited local anaesthetics.[18]

Liposomal Bupivacaine

In an attempt to increase the duration of local anaesthetics, a formulation of bupivacaine has been produced where the local anaesthetic molecule is loaded in multivesicular liposomes. This slow-release formulation of drug is able to delay the release of local anaesthetic and therefore extend the duration of pain relief for the patient for up to 72 hours, compared to unaltered bupivacaine traditionally providing up to 8 hours of analgesia. It has been demonstrated to be suitable for local infiltration leading to increased duration of action and subsequent sparing of other analgesic medications (such as opioids). The safety profile is currently being established and appears not to differ from that of bupivacaine with no additional incidence of adverse events being noted. Some trials have noted no difference in reducing the duration of analgesia of necrotic teeth from that of traditional bupivacaine.[19] That being said, additional trials with significant power are needed before its use can be recommended.

Local Anaesthetic Infusion Pumps For Localised Deposition At The Surgical Site

Following surgical procedures, clinicians must determine the most appropriate means of controlling any post-operative pain associated with the procedure. This can be accomplished by a variety of localised or systemic means (some of which have been noted previously), one of which is an emerging method of patient-controlled localised deposition of local anaesthetic at the site of injury or surgery. There are many examples of a patient-controlled local anaesthetic infusion pump such as the ON-Q pain pump being used for general medical surgery,[20] but there is still much research to be carried out about these infiltrating catheters and their potential benefit in treating the head and neck region, and possible intraoral applications.

Ultrasound-guided IAN Blocks

In order to negate mandibular anatomical differences in varied patient populations, the use of ultrasonography to visualise and direct the blockage of the IAN may prove worthwhile. Previous studies have either used Doppler ultrasound (i.e. indirect assessment) of the IAN position for local anaesthetic deposition or injected coloured dye on cadavers to assess proximity of injectate deposition to the IAN.[21] There are currently ongoing studies using B-mode ultrasound (i.e. direct assessment) to directly visualise the IAN while using intraoral ultrasound to guide intraoral inferior alveolar blocks on patients with subsequent objective pulpal anaesthesia testing.

CONCLUSION

This paper provides a review of the pharmacology, techniques, and advances of local anaesthesia use in dentistry and should serve as a baseline for understanding that general dental practitioners possess for safe treatment of patients. Clinicians are encouraged to continue to expand both their didactic knowledge and practical clinical skills through advanced reading, discussion with colleagues, continuing education courses and treatment of patients.

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