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TREATMENT

Local anesthetics in dentistry

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Abstract

Since the advent of their use over a hundred years ago, local anesthetics have continued to shape the field of dentistry and its specialties by providing the means with which to accomplish a multitude of procedures in an office setting without the need for a general anesthetic. In oral and maxillofacial surgery, local anesthetics have the added benefit of providing hemostasis to the surgical field, resulting in increased visualization and attenuation of blood loss. In addition, long-acting local anesthetics have become increasingly popular for the control of postoperative pain, mitigating the need for the prescription of narcotic pain medication. A variety of agents, both for topical use and for injection, are available on the market in the United States. While the mechanism of action of these local anesthetic agents is similar, each drug offers its own unique characteristics, allowing the practitioner to tailor his or her selection of local anesthetic to the needs of the patient and the demands of the procedure. The aim of this chapter will be to introduce the basic pharmacology of local anesthetic agents and to familiarize the reader with the variety of drugs currently available on the market, their unique properties, and potential risks and complications associated with their use.

Keywords Anesthesia · Local · Injection

Quick reference/description

Local anesthetics are a drug class that can provide secure and reliable loss of sensation and control of painful stimuli to permit patient comfort during dental and surgical procedures without the requirement of general anesthesia. All local anesthetic agents demonstrate similar effects, but each agent has its own unique features and characteristics. Hence, selection of an appropriate local anesthetic agent should be performed with utmost care and attention depending on the requirements of the patient and the procedure.

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Overview

Local anesthetic	Indications	Applications
Benzocaine	Improvement of patient comfort with local anesthesia injection Alternative to injected local anesthetic to relieve discomfort from: Oral mucosal lesions like aphthous ulcers Gingivectomy Extraction of exfoliating deciduous teeth Rubber dam clamp placement Scaling and root planning	Topical anesthetic agent that is available as a single agent or in combination with other topical anesthetics in the form of: Spray Gel Gel patches Ointments Solutions
Lidocaine	Improvement of patient comfort with local anesthesia injection Alternative to injected local anesthetic to relieve discomfort from: Oral mucosal lesions like aphthous ulcers Gingivectomy Extraction of exfoliating deciduous teeth Rubber dam clamp placement Scaling and root planning Radiation mucositis Injected local anesthetic for use in various dental procedures	Topical anesthetic agent that is available in the form of: Spray Gel Patches Ointments Solutions Mouthwash Injected lidocaine is available in two preparations in combination with epinephrine
Tetracaine hydrochloride	Improvement of patient comfort with local anesthesia injection Alternative to injected local anesthetic to relieve discomfort in common dental procedures	Topical anesthetic agent that is available in several forms in combination with other agents like lidocaine, tetracaine or phenylephrine
Eutectic mixture of local anesthetics (EMLA)	Improvement of patient comfort with local anesthesia injection As a topical anesthetic in minor soft-tissue procedures	A potent topical anesthetic for use on intact skin and genital mucous membranes only Use on oral mucosa is considered as "off-label"
Procaine	Injected local anesthetic for use in various dental procedures	Procaine is not available in North America anymore
Mepivacaine	Injected local anesthetic for use in patients requiring local anesthesia without vasoconstrictor	Injected local anesthetic agent that is available as a single agent or in combination with vasoconstrictor
Bupivacaine	Injected local anesthetic of choice for lengthy dental procedures and management of postoperative pain	Injected local anesthetic agent that is available as a solution in dental cartridges
Articaine	Injected local anesthetic for local infiltration for minor dental procedures in the maxilla	Injected local anesthetic agent that has a short onset of action with a superior anesthetic effect
Prilocaine	Injected local anesthetic for use in various dental procedures	Injected local anesthetic agent that is available in dental cartridges as a single agent or in combination with vasoconstrictor

Materials/instruments

- Benzocaine
- Lidocaine
- Tetracaine hydrochloride
- Eutectic mixture of local anesthetics (lidocaine and prilocaine)
- Procaine
- Mepivacaine
- Bupivacaine
- Articaine
- Prilocaine
- Dental cartridge

Procedure

Local anesthetics possess the ability to provide temporary intraoperative loss of sensation without the use of general anesthetic agents. This facilitates a safe and comfortable work environment for the patients and dental clinicians. While the mechanism of action of all local anesthetics is similar, each anesthetic agent has a unique set of features and characteristics. Hence, an appropriate local anesthetic agent can be carefully selected depending on the requirements of the patient as well as the procedure. Local anesthetics act by reversibly blocking the ion channels along the nerve fiber. This reduces the depolarization rate leading to failure of production of an action potential along the length of the nerve.

Local anesthetic agents can facilitate hemostasis in the surgical field and lead to decreased blood loss and improved visualization that is favorable in oral and maxillofacial surgery. Long-acting local anesthetics can effectively treat postoperative pain and limit the requirement for the prescription of opioid pain medications. The rationales for the frequent use of local anesthetics in dentistry and medicine are:

- Surgical anesthesia via infiltration or nerve blockade
- Combined use with general anesthetics
- Control of postoperative pain.

I. Composition of commercially available local anesthetics

Most of the commercially available local anesthetics contain three main components:

Local anesthetics

For clinical use, local anesthetics are available as acid salts. The potency of local anesthetics depends on their lipid solubility. They can be classified depending on their intermediate chain into (Table 1):

Table 1 Classification of local anesthetics

Ester-linked local anesthetics	Amide-linked local anesthetics
These agents are easily hydrolyzed in aqueous solution	These agents are slowly hydrolyzed in aqueous solution
Biotransformation of ester local anesthetics occurs primarily in the plasma by pseudocholinesterase and can be impaired in patients with pseudocholinesterase deficiency	Biotransformation of amide local anesthetics occurs in the liver and can be impaired in patients with severe liver dysfunction
Examples of ester local anesthetics: benzocaine, tetracaine, procaine	Examples of amide local anesthetics: lidocaine, mepivacaine, bupivacaine, articaine (also possesses an ester ring), and prilocaine

Vasoconstrictor

As most local anesthetic agents are vasodilators, a vasoconstrictor is added for blood vessel constriction to delay redistribution of the drug and prolong the duration of anesthesia. This is also helpful in decreasing systemic drug toxicity, enhancing hemostasis at the surgical site and improving surgical field visibility by attenuating blood loss during surgery. Epinephrine and levonordefrin are the commonly available vasoconstrictors for use in combination with local anesthetics.

The use of vasoconstrictors in patients with cardiovascular disease remains controversial due to the physiologic changes on the cardiovascular system caused by vasoconstrictors. Patients with cardiovascular disease can tolerate small doses of vasoconstrictor-containing local anesthetics well. According to Malamed, the maximum safe dosage of epinephrine in patients with cardiovascular disease is 40 μg, while as per Little, it is 36 μg or '1–2 carpules' if local anesthetic solutions with 1:100,000 epinephrine are used.

Other dental cartridge components

To prolong the shelf-lives of vasoconstrictor-containing local anesthetic agents, antioxidants like sodium bisulfite are used. In patients with a true sulfite allergy, use of sodium bisulfite-containing local anesthetic solutions is contraindicated. The standard dental cartridge also contains sodium chloride for tonicity and distilled water for volume maintenance.

Local anesthetics can also be divided into two subgroups, namely, topical and injected local anesthetics.

II. Topical anesthetics

Topical anesthetics are utilized to enhance patient comfort associated with local anesthesia injection. Topical anesthetic agents can also be used as an alternative to injected local anesthetic agents for relief from pain due to aphthous ulcers, or during minor dental procedures like:

- Gingivectomy
- Extraction of exfoliating deciduous teeth
- Rubber dam clamp placement
- Scaling and root planning

To achieve a desirable effect of the topical anesthetic, it must be active during application to the mucosa. Local anesthetics like procaine, mepivacaine, and articaine are ineffective as topical agents. Depending on the administration site, the time for onset of action of topical anesthetics is 30 s to 2.5 min. These agents have a penetration depth of 2–3 mm. When used in combination with injected local anesthetics, topical agents should be administered carefully to avoid local and systemic toxicity due to their varying composition, difficult dosing, and low therapeutic index.

Benzocaine

In dentistry, the most commonly used topical anesthetic is benzocaine. The use of benzocaine is considered safe as it is mostly insoluble in water with poor systemic absorption, thereby decreasing the risk of systemic toxicity. Benzocaine is used as a single agent or in combination with other topical anesthetics at concentrations of 10–20%. It is commercially available in the form of sprays, gels, gel patches, ointments, and solutions.

Intraoral use of unmetered spray devices should be performed with careful patient monitoring as there is a risk of methemoglobinemia in association with topical benzocaine application, particularly in elderly patients and neonates. Topical benzocaine use can also cause allergic reactions like contact dermatitis.

Lidocaine

Topical application of lidocaine is commonly performed in dentistry and medicine. Lidocaine is water soluble in nature with higher systemic absorption requiring careful administration, especially in pediatric patients. It is commonly available as a single-agent ointment in a 2% water-soluble form or a 5% base form. The use of topical lidocaine by pediatric dentists as an alternative to injected local anesthetics for minor procedures like primary teeth exfoliation is prevalent.

Topical lidocaine is also available in the form of sprays, gels, patches, and viscous solutions. The viscous solutions are formulated in concentrations of 0.5%, 1%, and 2% that are used for preparation of a ‘magic mouthwash’ for symptomatic relief from aphthous ulcers and radiation mucositis. Lidocaine is associated with a minimal risk of allergic reaction.

Tetracaine hydrochloride

Topical application of tetracaine can be used for local anesthesia on mucous membranes, as in for dental procedures, or on the skin. It is highly potent and water soluble

in nature. Tetracaine has a slow onset of action and rapid mucosal absorption resulting in a high risk for systemic toxicity. Hence, its use over large sites is considered inappropriate.

Tetracaine is commonly available in dentistry in conjunction with the other agents. One such compound is TAC 20 percent Alternate that contains 20% lidocaine, 4% tetracaine, and 2% phenylephrine. Profound is another tetracaine-containing compound that was formulated initially for use in soft-tissue laser surgery and contains a mixture of 10% lidocaine, 10% prilocaine, and 4% tetracaine. To achieve anesthesia of the maxillary teeth, a nasal spray of 3% tetracaine compounded with oxymetazoline can be used.

Eutectic mixture of local anesthetics (EMLA)

EMLA is another commonly used compound topical anesthetic cream. It is a 2.5% lidocaine and 2.5% prilocaine emulsion formulated as eutectic oil. It can penetrate intact skin easily. EMLA is effective as a topical agent before venipuncture predominantly in pediatric patients and in various minor soft-tissue procedures. The EMLA cream is applied to the desired site and covered with an occlusive dressing for a minimum of 60 min for the desired local anesthetic effect. The maximum effect of EMLA occurs after 2–3 h of application. Superficial dermal anesthesia persists for about 1 h after removal of the EMLA cream.

EMLA is indicated only for genital mucous membranes and intact skin. Its use on the oral mucosa is considered as 'off-label', even though it has a significant anesthetic effect on the oral mucosa, as well.

III. Injected local anesthetics

A variety of injected local anesthetic agents are available in dental cartridges with or without a vasoconstrictor. The selection and maximum dosing of an appropriate injected anesthetic agent depend on several factors like the following given in Table 2.

Table 2 Factors affecting selection of injected local anesthetic agent

Drug-related factors	Patient factors	Operator-related factors
Time of onset	Individual patient response	Method of administration
Duration of action	Age of the patient	Accuracy of administration
Maximum allowable dose	Anatomic variation	
Use of two or more agents in one patient	Tissue conditions	
	Medically compromising conditions	

Procaine

The first synthetic anesthetic agent introduced was procaine. It was marketed as novocaine and is no longer available in North America. Procaine has low potency, slower onset, and short duration of action with a high allergic potential. It has been replaced by newer local anesthetic agents.

Lidocaine

The most commonly used injected local anesthetic in dentistry and medicine is lidocaine. Lidocaine is considered as the standard injected local anesthetic agent and is safe, effective, and reliable. According to the American Academy of Pediatric Dentistry, the maximum dose of lidocaine with epinephrine should not exceed 4.4 mg/kg in the pediatric patient, while the FDA has approved a maximum dosage of 7.0 mg/kg for both adult and pediatric patients, but the maximum total dose should not exceed 500 mg.

In North America, lidocaine is available in two preparations, namely, 2% lidocaine with 1:100,000 epinephrine and 2% lidocaine with 1:50,000 epinephrine. The preparation with 1:50,000 epinephrine shows more significant hemostasis than the 1:100,000 epinephrine preparation. Both the preparations have similar characteristics like:

- Onset—less than 2 min for local infiltration and 2–4 min for nerve blockade.
- Duration of action—pulpal anesthesia and soft-tissue anesthesia for 1 h and 2.5 h, respectively, after local infiltration. After nerve blockade, pulpal anesthesia and soft-tissue anesthesia for 90 min and 3 h, respectively.
- Maximum recommended dosage.

Mepivacaine

Mepivacaine is pharmacologically similar to lidocaine. It is available in dental cartridges as a 2% solution compounded with levonordefrin. Mepivacaine is also available as a 3% single-agent solution. The vasodilatory properties of mepivacaine are less potent and do not necessarily require the addition of vasoconstrictor to facilitate a clinically acceptable duration of anesthesia. Hence, mepivacaine 3% single-agent solution is frequently utilized in patients requiring restricted use of vasoconstrictors. This solution is mainly indicated for short-duration procedures without the need for profound pulpal anesthesia.

Alternatively, mepivacaine is available as a 2% solution compounded with 1:100,000 or 1:50,000 epinephrine, or 1:20,000 levonordefrin. The maximum recommended dose of mepivacaine 3% single-agent solution and mepivacaine 2% with vasoconstrictor is 6.6 mg/kg and, the absolute maximum dosage of mepivacaine is 400 mg.

Bupivacaine

Bupivacaine is the anesthetic of choice for long dental procedures or for the management of postoperative pain. It has a slower onset time of 6–10 min and a long

duration of action resulting in pulpal anesthesia of about 90–180 min and soft-tissue anesthesia of about 4–9 h. Bupivacaine is widely used for postoperative pain management along with non-steroidal anti-inflammatory drugs and can decrease or completely eliminate the need for narcotic analgesics. It is available in dental cartridges as a 0.5% solution with 1:200,000 epinephrine. The maximum dosage recommendation for bupivacaine by the FDA is 90 g in a healthy adult and is not weight-based.

Bupivacaine is not recommended in young children or in patients with delayed development to avoid unintentional self-mutilation because of the prolonged soft-tissue anesthesia. It has also been associated with severe reactions especially following accidental overdose leading to increased cardiotoxicity.

Articaine

Articaine is the only amide local anesthetic agent with a thiophene ring that increases its lipid solubility. Another unique feature of articaine is that it contains an ester group and is metabolized both in the blood by plasma esterases and in the liver. It has a short onset time of 1–9 min with peak blood levels at 25 min. 4% articaine shows similar onset, duration and quality of anesthesia to 2% lidocaine when used for local infiltration for minor dental procedures in the maxilla. Maxillary buccal infiltration with 4% articaine can also help in achieving palatal anesthesia, thus eliminating the requirement for additional painful palatal injections.

Nerve blockade with articaine can increase the risk of paresthesia due to neurotoxicity. Therefore, 4% articaine should not be used for nerve blockade if other viable alternatives are available.

Prilocaine

Prilocaine is commonly available in dental cartridges as a 4% concentration in solution with 1:200,000 epinephrine and without epinephrine. The single-agent solution is used to limit the dosage of epinephrine, particularly in patients with severe cardiovascular disease. It is unique in that its metabolism takes place in the kidney and plasma. The maximum recommended dosage of prilocaine with or without epinephrine is 8.0 mg/kg up to a total of 600 mg. As prilocaine is metabolized in several sites, the plasma levels reduce rapidly and cause less systemic toxicity. Nerve blockade with prilocaine can increase the risk of paresthesia. Therefore, 4% prilocaine should not be used for nerve blockade if other viable alternatives are available.

Prilocaine is associated with the development of acquired methemoglobinemia. Peak levels of methemoglobin can be attained after 3–4 h of prilocaine administration. Weakness, nausea, vomiting, tachycardia, and respiratory distress are the symptoms of methemoglobinemia. Continued increase in methemoglobin blood concentrations can cause lethargy and stupor. If methemoglobin levels rise above 70% without intervention, the condition can be fatal. Methemoglobinemia is diagnosed if a cyanotic patient has chocolate brown appearance of the blood and is unresponsive to supplemental oxygen administration. 1% methylene blue (1.5 mg/kg) should be administered immediately.

The operator should keep in mind that a patient with methemoglobinemia can have normal partial pressures of oxygen with falsely increased level of oxygen saturation on pulse oximetry. The use of prilocaine is relatively contraindicated in patients with a history of congenital methemoglobinemia.

Pitfalls and complications

- The local complications associated with the use of local anesthetics are:
  - Paresthesia
  - Prolonged anesthesia
  - Soft-tissue injury
  - Hematoma
  - Trismus
  - Ocular complications like blurry vision, temporary blindness, mydriasis, ptosis, diplopia, or ophthalmoplegia
  - Facial nerve palsy
- The systemic complications associated with the use of local anesthetics are:
  - Local anesthetic overdose and drug toxicity
  - Methemoglobinemia
  - Allergy
- The biotransformation of amide local anesthetics can be affected in patients with severe liver dysfunction, while that of ester local anesthetics can be affected in patients with pseudocholinesterase deficiency resulting in an increased risk of toxicity.

Further reading

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