BRITISH JOURNAL OF HOSPITAL MEDICINE
MMC Modernising Medical Careers

MODERNISING MEDICAL CAREERS

IN NEXT MONTH'S MMC SUPPLEMENT

Teaching styles: a guide for the foundation year doctor

Management of foreign bodies in the ears and upper aerodigestive tract

Breast abscess

How to insert a temporary pacing wire

Local anaesthesia and its safe use in minor surgery

Introduction

Local anaesthetics are drugs that are used clinically to produce reversible inhibition of excitation and conduction in peripheral nerve fibres and produce loss of sensation in a circumscribed area of the body. Local anaesthetics have a common structure (*Figure 1*) with a lipophilic (aromatic) group joined to a hydrophilic (amine) group by an intermediate chain. This intermediate chain may be either an amide or ester link, hence the two major groups of local anaesthetics are esters and amides (*Figure 2*). The linkage is important because of the metabolism of that group which has, in the case of esters, led to adverse reactions and limited their use. Knowledge of the physicochemical properties of a local anaesthetic is important as they influence the pharmacodynamics of that drug.

Figure 1. Basic structure of local anaesthetic.

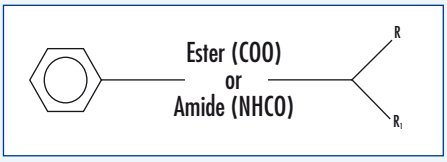
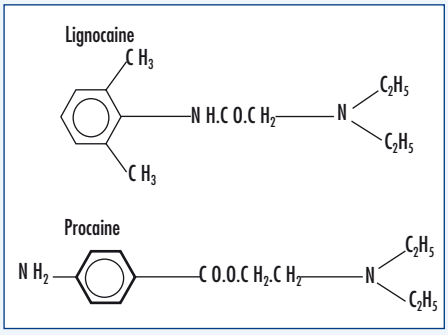


Figure 2. Structure of an amide (lignocaine) and an ester (procaine).



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Mechanism of action

Local anaesthetics act by blocking sodium channels in neural tissue and thereby preventing depolarization and propagation of the action potential along the nerve (*Figure 3*). The onset, duration of action and potency of any particular agent can be predicted from various characteristics.

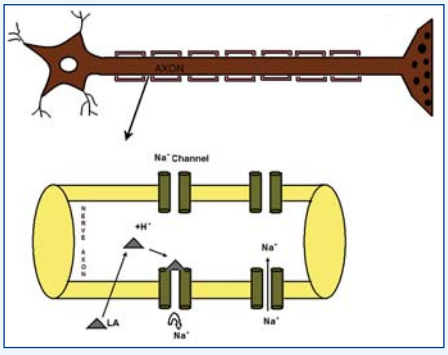
Potency will relate to lipid solubility while duration of action will be affected by protein binding (high protein binding leading to a general increase in duration of action) as well as removal of free drug from the site of action (blood supply). The onset of action will be determined by the pKa (the dissociation constant, i.e. the pH at which 50% of the drug is ionized and 50% is un-ionized) as it is only the un-ionized form that can cross the nerve membrane and bind to the sodium channel. Local tissue pH (e.g. acidosis associated with infection) will therefore affect the degree of ionization and onset of action.

Toxicity

Central nervous system

As local anaesthetics can cross the blood–brain barrier they will block sodium channels on CNS tissue as well. The amide group has a biphasic effect – initially having an anticonvulsant or depressive effect

Figure 3. Diagram demonstrating a nerve sheath and how local anaesthetics (LA) act on the sodium channels in neural tissue.



followed by excitation (depression of inhibitory pathways) and fits. Clinically, if plasma concentration rises relatively slowly, the patient may describe symptoms including perioral tingling, dizziness, visual disturbance and tremors. Coma and apnoea will occur with plasma concentrations of around 2 mg/ml and 9 mg/ml for bupivacaine and lidocaine respectively.

Cardiac

Cardiac toxicity usually follows CNS toxicity and may cause bradycardia, profound hypotension and life-threatening arrhythmias. This occurs because, in addition to action on sodium channels, local anaesthetics also act on myocardial potassium and calcium channels. They also have a direct depressant action on cardiac conduction causing widening of QRS complex, ST segment changes and in high concentrations can lead to re-entrant phenomena, ventricular arrhythmias and cardiac arrest. Lidocaine is safer than bupivacaine in this respect but recently levobupivacaine (S-bupivacaine) and ropivacaine (an S-isomer) have shown promise as they dissociate more rapidly from cardiac sodium channels and are therefore potentially less toxic.

Treatment of toxicity

- Stop injection or infusion
- Airway, breathing and circulation
- Mild symptoms may be managed with just oxygen and fluids. Midazolam may be helpful as it increases the convulsion threshold
- Moderate to severe toxicity often requires intubation, ventilation and treatment with vasopressors
- Severe toxicity is usually refractory to the above treatment and use of Intralipid 20% (Fresenius Kabi, Sweden) may be beneficial
- A patient fainting is not uncommon but local anaesthetic toxicity is uncommon and therefore it is imperative to exclude other conditions.

Individual drugs

Cocaine, amethocaine and procaine are examples of ester local anaesthetics, while lidocaine, prilocaine, bupivacaine and ropivacaine are part of the amide group. *Table 1* summarizes the physicochemical properties and pharmacological effects of the commonly used drugs in clinical practice.

Cocaine is commonly used for topical anaesthesia and local vasoconstriction. It is short acting and has a slow onset. It is used in the nasal cavity as a 5% or 10% solution to provide vasoconstriction. It is a sympathomimetic and can cause numerous side effects such as seizures, confusion, hallucinations, hyperthermia, hypertension and arrhythmias. It has become less popular nowadays because of its potential for side effects and its use as a drug of dependence and abuse.

Amethocaine is available as 0.5% and 1% and is mainly used topically or as a sole agent for lens surgery. It is also available as 4% Ametop cream, which can be used before venous cannulation. It has a faster onset of action than EMLA cream, providing topical anaesthesia by 30 minutes and its effect lasts for 4–6 hours. It releases histamine, which may result in local vasodilatation and erythema.

Lidocaine, a short-acting amide with a fast onset, is available in a number of different formulations, including as a 0.5–2% solution with or without adrenaline (1 in 80 000–200 000), 2% gel, 5% ointment, nebulizer delivering 10 mg per dose, 4% topical solution and also in suppository form in combination with steroid. Its clearance is reduced in the presence of hepatic or cardiac failure as it is mainly metabolized in the liver. Intravenous lidocaine can be used to control ventricular arrhythmias effectively.

Prilocaine (0.5–2%) has similar indications to lidocaine but is most frequently used for intravenous regional anaesthesia (e.g. Bier's block). It is shorter acting, has a slower onset of action and is relatively safer. EMLA cream, a combination of 2.5% lidocaine and 2.5% of prilocaine, is useful for venous cannulation or harvesting for skin grafts. It may precipitate methaemoglobinaemia in large doses, which may require treatment with ascorbic acid or methylene blue.

Bupivacaine, a racemic mixture of R and S enantiomers, is a longer acting amide as it is highly protein bound. However, the onset of action is significantly slower than lidocaine. It is available in concentrations varying from 0.1 to 0.75%. It has been the mainstay of epidural infusions postoperatively and in labour. It is also commonly used in spinal anaesthesia. Concerns regarding the cardiac toxicity of the R-enantiomer have led to the development of ropi-

Table 1. Physicochemical and pharmacological properties of commonly used local anaesthetics

	pKa	Onset	Potency	Duration of action	Clinical use	Properties
Lidocaine	7.7	Fast	Medium	Medium	Infiltration anaesthesia Intravenous regional anaesthesia Regional anaesthesia	Versatile Moderate vasodilatation
Prilocaine	7.7	Fast	Low	Medium	Infiltration anaesthesia Intravenous regional anaesthesia Peripheral nerve blockade	Low systemic toxicity May cause methaemoglobinaemia
Bupivacaine	8.1	Slow	High	Long	Infiltration anaesthesia Regional anaesthesia	Separation of sensory and motor blockade
Levobupivacaine	8.1	Slow	High	Long	Infiltration anaesthesia Regional anaesthesia	Reduced cardiac toxicity
Ropivacaine	8.1	Slow	High	Long	Infiltration anaesthesia Regional anaesthesia	Better separation of sensory and motor blockade Reduced motor blockade

vacaine, which is a pure S-enantiomer. Ropivicaine, in addition to providing an improved toxicity profile, gives a better sensory/motor discrimination because the motor block produced is slower in onset, less dense and of shorter duration compared with an equivalent dose of bupivacaine. For this reason it is becoming more widely used in regional anaesthesia.

How to administer

Topical anaesthesia may be applied to the skin, eyes, nose, ears or mouth as well as other mucous membranes in the tracheobronchial tree and genitourinary tract. It can be used to produce anaesthesia for minor surgical procedures like diagnostic urological and procedures, some ophthalmic surgery, suturing of episiotomy wounds, minor lacerations and dental surgery. Lidocaine, prilocaine, cocaine and amethocaine are the commonly used agents.

Infiltration anaesthesia (*Figure 4*) is commonly used in minor surgery and dentistry. The onset of action is almost immediate after submucosal or subcutaneous injections and provides satisfactory operating conditions in over 90% of cases. Residual anaesthesia persists longer after intradermal injection (4–7 hours) than after submucosal injection. Lidocaine and prilocaine have a moderate duration of action (70–140 minutes) whereas bupivacaine and ropivacaine have longer duration (200 minutes).

Conduction anaesthesia can not only be used for blocking single nerves like the digital nerve (*Figure 5*), median nerve (*Figure 6*), radial nerve, ulnar (*Figure 7*) and intercostals but also is commonly used for major blockade of nerve trunks (e.g. brachial plexus, lumbar plexus). Amide local anaesthetics have a relatively rapid onset of action for producing minor nerve blockade (3–6 minutes). Mixtures of local anaesthetic agents (e.g. lidocaine and bupivacaine) are used to combine rapid onset with prolonged duration of action. The onset of action is prolonged and variable in major nerve blockade because the local anaesthetic must diffuse across tissue barriers as well as myelin sheaths of nerve trunks. In general, lidocaine takes about 14 minutes and bupivacaine takes about 23 minutes to act and analgesia persists for 3–4 hours for lidocaine and 12 hours or more with bupivacaine. Adjuncts such as opioids, ketamine and clonidine have been used to prolong the duration of analgesia.

Intravenous local anaesthesia (Bier's block) is a useful method of providing analgesia for minor surgical procedures. It involves slow injection of local anaesthetic into a vein of a limb that has been exsanguinated and occluded by a tourniquet, which is inflated to 100 mmHg above systolic blood pressure. This causes paraesthesia and analgesia immediately and sensory blockade usually develops within 10 minutes. Tourniquet pain can be avoided by using a double tourniquet. Lidocaine and prilocaine are commonly used and it is wise to avoid bupivacaine because of its cardiac toxicity. Systemic toxicity is usually associated with accidental or inadvertent deflation of the tourniquet.

Tumescent anaesthesia involves infiltration of large volumes of lidocaine and adrenaline into the targeted fatty tissues and these areas become swollen and firm (tumescent). It produces profound anaesthesia for skin and subcutaneous tissue for many hours. Lidocaine, which is bound to the fatty tissue, is released slowly but steadily into the systemic circulation. Since adrenaline reduces the perfusion, systemic uptake of the drug keeps in pace with the clearance of lidocaine except in people with altered function of cytochrome p450. It is possible to use huge volumes of local anaesthetics, up to 35 mg/kg of lidocaine, without any apparent ill effects. Although mainly used in plastic surgery, e.g. liposuc-

Figure 5. Digital nerve block.

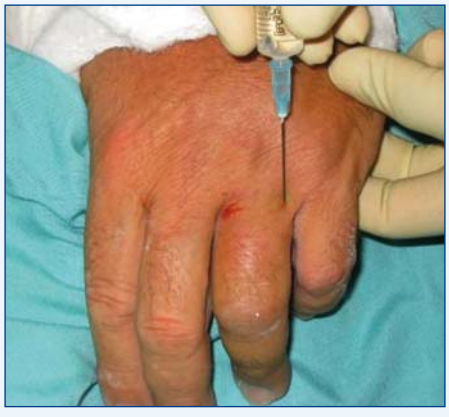


Figure 4. Field block. a. Encircle and infiltrate around a small area. b. Raise a second weal through this and repeat until the lesion is encircled.

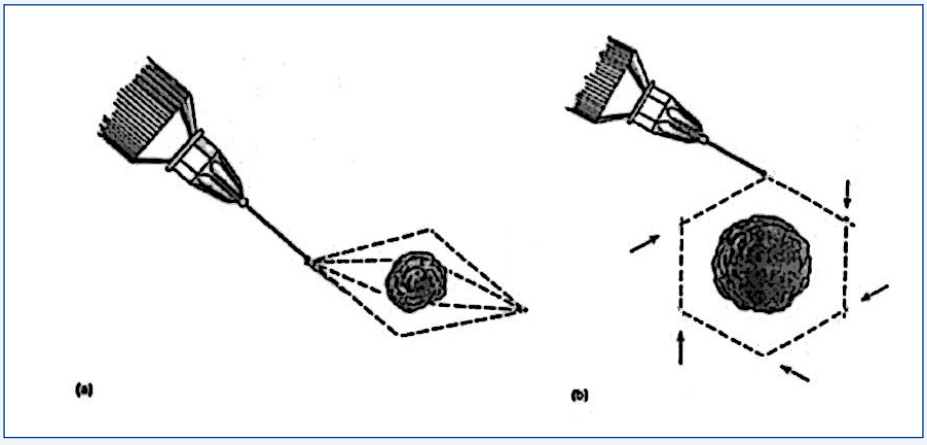


Figure 6. Median nerve block.

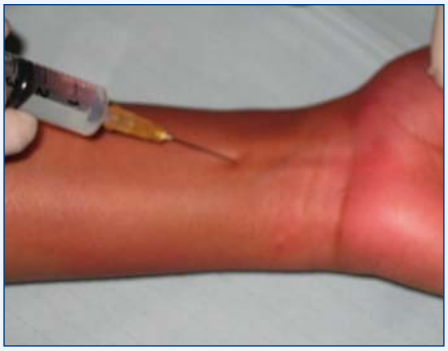
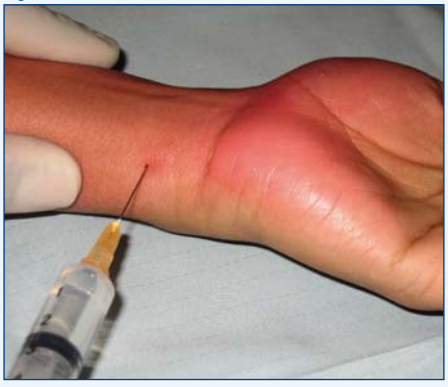


Figure 7. Ulnar nerve block.



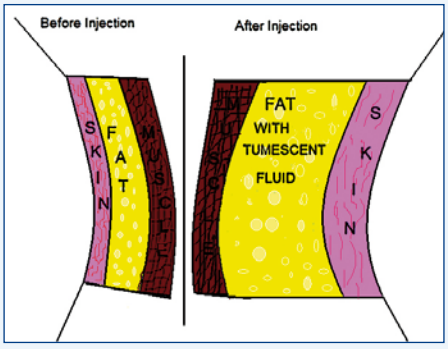


Figure 8. Tumescent anaesthesia.

tion, abdominoplasty and face lifts, it has also been used for varicose vein stripping, skin grafting and hair transplantation (*Figure 8*).

The maximum recommended doses of commonly used local anaesthetic agents are summarized in *Table 2*. In real terms these mean (for an average 70 kg man), for plain lidocaine 40 ml 0.5% (200 mg), 20 ml 1% (200 mg) or 10 ml 2% (200 mg); for bupivacaine (+/- adrenaline) 25–30 ml 0.5% (125–150 mg) or 50–60 ml 0.25% (125–150 mg); or for lignocaine + adrenaline approximately double.

Additives

Many substances can be added to local anaesthetic for pharmacological reasons (*Table 3*).

What to do

- Informed verbal and or written consent should be obtained
- Consider local anaesthetic first if it is a safer alternative to general anaesthetic especially in high-risk patients
- Always discuss potential complications, side effects and document them
- Always identify the site/side correctly and perform the technique in an appropriate setting with resuscitation equipment and drugs available
- Always have intravenous access and minimal monitoring standards
- Follow strict asepsis
- Calculate the dose according to the patient's age, weight and the drug to be used
- Allow antiseptic solution to dry before injecting local anaesthetic
- Use small gauge needles (>22G) and inject slowly
- Be prepared to deal with potential complications and/or toxicity
- Always document the procedure carried out, recording complications.

What not to do

- Patient's refusal and local sepsis are absolute contraindications
- Caution during nerve blockade if the patient is on anticoagulant therapy
- Never inject the drug without aspirating
- Never inject if the patient complains of pain or if there is resistance
- Never use vasoconstrictors along with local anaesthetic near end arteries, e.g. digits, nose, ear and penis, as they may lead to ischaemia and gangrene. BJHM

Conflict of interest: none.

Further reading

Covino BC (1986) Pharmacology of local anaesthetic agents. *Br J Anaesth* **58:** 701–16

Picard J, Meek T (2006) Lipid emulsion to treat overdose of local anaesthetic: the gift of the glob. *Anaesthesia* **61**(2): 107

Reynolds F (1987) Adverse effects of local anaesthetics. *Br J Anaesth* **59:** 78–95

Samdal F, Amland PF, Bugge JF (1994) Plasma lidocaine levels during suction assisted lipectomy using large doses of dilute lidocaine with epinephrine. *Plast Reconstr Surg* **93:** 1217–23

Scott DB (1986) Toxic effects of local anaesthetic agents on the central nervous system. *Br J Anaesth* **58:** 732–5

Taylor B, Bayat A (2003) Local anaesthesia. *Student BMJ* **11:** 227–9

Table 2. Maximum recommended local anaesthetic doses

	Adult dose (mg)		mg/kg equivalent	
	Plain	With adrenaline	Plain	With adrenaline
Prilocaine	400	600	6	8
Lidocaine	200*	500	3	7
Bupivacaine	150†	150‡	2	2
Levobupivacaine	150	150	2	2
Ropivacaine	250	N/A	3.5	N/A

* 300 in USA; † 175 in USA; ‡ 225 in USA

Table 3. Additives used with local anaesthetics in minor anaesthetic surgery

Drugs	Properties and clinical uses
Vasoconstrictors	Reduces local vascularity and systemic uptake thereby increasing duration of nerve blockade, providing greater margin of safety and reducing surgical bleeding
1. Adrenaline	Most potent agent Use dilute solution (<1:200,000, maximum dose not > 0.5 mg)
2. Felypressin	Safer drug usually used in dental practice Coronary circulation may be compromised
Carbon dioxide	Carbonated salts lower intracellular pH and produces more ionized form thereby bringing a faster onset of blockade
Hyaluronidase	Added to aid spread by breaking tissue barriers Used currently in ophthalmic and plastic surgery

KEY POINTS

- As different local anaesthetics have different physicochemical properties, one drug may offer certain advantages over another. Understanding these properties will enable the practitioner to choose the right drug for the right procedure.
- Serious toxicity of local anaesthesia can manifest as cardiovascular or neurological symptoms, but is fortunately rare.
- All practitioners using local anaesthetic need to recognize and treat symptoms of toxicity.
- The most important aspect of using local anaesthetic or performing nerve blocks is to ensure that there is no compromise on safety at any cost.