BRITISH JOURNAL OF HOSPITAL MEDICINE

REVIEW

The what, why and when of wide awake local anaesthesia no tourniquet surgery

Jamal Khudr[1]

Luke Hughes[2]

Fizan Younis[2]

Author details can be found at the end of this article

Correspondence to:
Jamal Khudr;
jkhudr@gmail.com

Abstract

Wide awake local anaesthesia no tourniquet, also known as WALANT, is the practice of performing surgery under local anaesthetic in the absence of a tourniquet. This technique uses the vasoconstrictive effects of adrenaline and the local anaesthetic effects of lignocaine to establish a Bier block with haemostatic control. Permitting active patient participation intraoperatively, wide awake local anaesthesia no tourniquet surgery improves patient compliance with rehabilitation and yields higher patient satisfaction. With reduced cost and equipment requirements, this method improves accessibility for patients and productivity for healthcare institutions. This is of particular benefit within the current COVID-19 climate, as wide awake local anaesthesia no tourniquet technique provides a means of overcoming restrictions to theatre access and anaesthetic support. This review delves into the current uses of wide awake local anaesthesia no tourniquet surgery, outlining the initial conception of the practice by Canadian surgeons. The advantages and disadvantages are considered, and potential future applications of this technique are discussed.

Key words: Anaesthesia; Cost-effective; COVID-19; Hand surgery; No tourniquet; Safe; Walant; Wide awake

Submitted: 7 July 2021; accepted following double-blind peer review: 4 August 2021

Introduction

This article defines the term 'wide awake surgery, local anaesthetic, no tourniquet', providing details of its inception and evolution. The authors outline the current uses of this technique, alongside the perceived advantages and disadvantages, and discuss the potential advances of this technique and how these could broaden its use.

Definition

Wide awake local anaesthesia no tourniquet surgery is the practice of operating with the patient awake, using local anaesthesia in the absence of a tourniquet (Lalonde, 2016). This technique uses two primary agents, one for analgesia and the other for haemostasis, in most cases giving lignocaine and adrenaline respectively. By administering large volumes of local anaesthetic, to the point of producing swelling of the area, a form of extravascular Bier block is created. This negates the need for a general anaesthetic and/or regional block, avoiding the associated risks and permitting the patient to observe and participate in the operation, while avoiding any associated motor blockade. Haemostasis is achieved through local vasoconstriction. This not only limits systemic absorption of the local anaesthetic agent, such that greater doses may be used to achieve a larger operative field, but also obviates the need for a proximal tourniquet, which can be painful when applied for a prolonged period.

How to cite this article:
Khudr J, Hughes L, Younis F. The what, why and when of wide awake local anaesthesia no tourniquet surgery. Br J Hosp Med. 2022. https://doi.org/10.12968/hmed.2021.0383

A history of wide awake local anaesthesia no tourniquet surgery

'Do not inject adrenaline into fingers, nose, penis and toes' (Lalonde, 2016); the fear of necrosis secondary to adrenaline injection was widespread before the 1950s, taught to all medical students and deeply engrained in surgeons. The theory was that the vasoconstriction observed following the use of adrenaline caused distal ischaemia, which in turn resulted in cell death of the distal extremities. This myth is associated with the use of procaine, the

only safe local anaesthetic for injection at that time (Thomson et al, 2007). Procaine, with a base pH of 3.6, becomes increasingly more acidic as it degrades, reaching a pH as low as 1. This degradation process is significantly accelerated at higher temperatures and with time. This toxic acidity has implications for the pathogenesis of soft tissue necrosis, and a landmark paper published by the Food and Drug Administration (1948) attributed finger necrosis to procaine, rather than adrenaline.

Papers eventually began to disprove the myth of necrosis secondary to adrenaline injection. After reviewing the literature between 1800 and 2000, Denkler (2001) reported that there were no recorded cases of finger necrosis after an injection of adrenaline. When combined with the development of phentolamine as an adrenaline rescue agent, it was considered safe to establish trials examining the role of adrenaline and finger necrosis (Lalonde, 2016).

The wide awake local anaesthesia no tourniquet technique was spearheaded by Dr Lalonde, a plastic and hand surgeon who was limited by the number of anaesthetists present at his hospital. This shortage of anaesthetists was prevalent throughout the Canadian healthcare system and created a need for alternative techniques that could allow minor surgery to be performed in a sterile non-theatre setting. Lalonde et al (2005) established the Dalhousie project, a prospective study of 3110 consecutive elective cases where adrenaline was injected into the hand and finger to investigate the associated occurrence of digital infarction, skin necrosis or tissue loss of any kind. The authors did not report any cases of finger necrosis or cases where the reversal agent phentolamine was required. These findings were echoed in subsequent studies investigating the elective and accidental high-dose administration of adrenaline, including one where an adrenaline concentration of 1:1000 was used (100 times the concentration used in previous trials) (Fitzcharles-Bowe et al, 2007).

Pharmacology

Local anaesthetic agents act on intracellular sodium channels to inhibit the influx of sodium ions across the neuronal membrane. This prevents depolarisation of the membrane, which in turn prevents the production of action potentials, so the pain signal is not conducted along the neuron. Local anaesthetics have a higher affinity for sodium channels in an activated state and as such, onset of action is faster in rapidly firing neuronal fibres (Figure 1). There are two main groups of local anaesthetics that are characterised by their molecular linkages. Esters, which include cocaine and procaine, are metabolised by pseudocholinesterase and are more likely to produce allergic reactions, and amides, which include lignocaine and bupivacaine and are metabolised by the liver (Taylor and McLeod, 2020).

Local anaesthetic agents are usually combined with adrenaline, also known as epinephrine, a naturally occurring catecholamine primarily produced by the adrenal glands, which acts on both alpha-adrenergic receptors and beta-adrenergic receptors. Adrenaline is used in hand surgery as its strong alpha-adrenergic stimulation induces local vasoconstriction. Adrenaline usually has a short plasma half-life of 2–3 minutes. However, because of local vasoconstriction, when injected subcutaneously the plasma half-life of adrenaline may increase, with effects lasting up to 1–2 hours (Hameln Pharma Ltd, 2020).

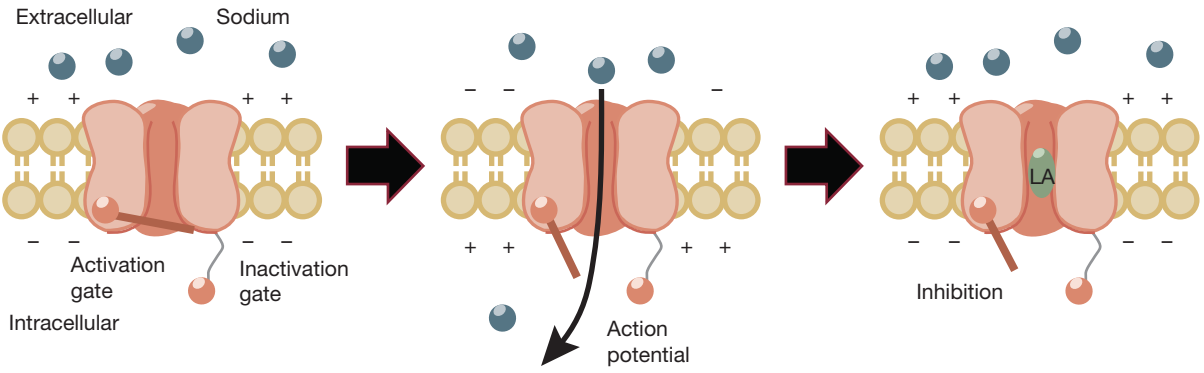

Figure 1. Mechanism of action of local anaesthetic on sodium channels to inhibit the flow of sodium ions across the channels and prevent the depolarisation of the neuronal membrane.

Amide anaesthetic agents are most commonly used in hand and wrist surgery. Lignocaine provides a rapid onset of anaesthesia, between 2 and 5 minutes, and intermediate duration, with anaesthetic effects lasting approximately 2 hours. When combined with adrenaline, the resulting vasoconstriction not only reduces the bleeding but delays the reabsorption of the local anaesthetic agent. This reduces the time until onset of action and increases the duration of action (up to 4 hours) (Swain et al, 2017). As a result of the delayed absorption the combined use of adrenaline protects against toxicity, allowing the maximum dose of lignocaine to increase from 3–7 mg/kg (Taylor and McLeod, 2020). In comparison, bupivacaine has a much slower onset of action, taking about 5–10 minutes after injection, yet lasting up to 2–4 hours. While the use of a vasoconstrictor has an unknown effect on the onset of bupivacaine, the use of adrenaline prolongs the duration of action (up to 7 hours) and protects against toxicity, allowing for an increased dosage from 2.5–3.0 mg/kg (Azar et al, 2020). It is important to note that when bupivacaine is used for finger block anaesthesia, the length of duration causes a digital pain sensation to return to the injected digit before the normal sensation returns. Patients may complain of discomfort as their fingers are still numb but hurt, because pain numbness can last up to 15 hours, while touch and pressure numbness can last up to 30 hours (Silva Neto et al, 2020).

Adding a buffer solution, usually 8.4% bicarbonate (1 ml per 10 ml solution), speeds up the anaesthetic onset and reduces pain upon administration (Kattan et al, 2019). It does so by making the pH of the anaesthetic agent closer to that of human tissues, equalising ion concentrations between the interstitial space and cell membrane and facilitating the flow of unionised local anaesthetic into the cells. The benefit is greatest in acidic tissues, as is the case during an infection, wherein the higher concentration of hydrogen ions reduces the efficacy of the analgesic agent.

When using large doses of local anaesthetic agents, it is also important to consider the effects of toxicity. Systemic local anaesthetic toxicity usually presents itself with CNS and cardiovascular system disruptions. Sodium channel blockage of cortical inhibition pathways may lead to sensory and visual changes, with muscular involvement presenting as convulsions. If plasma levels of local anaesthetic continue to increase, cortical excitatory pathways become compromised, producing latent features consisting of loss of consciousness, coma and eventual respiratory arrest. These CNS effects are more common and tend to present before any cardiovascular system effects (El-Boghdadly et al, 2018). Cardiotoxic symptoms are the consequence of rhythm disruptions which occur following sodium channel inhibition at the bundle of His, resulting in the impaired propagation of action potentials. This presents as a prolongation to the PR, QRS, and ST intervals, and bradyarrhythmias causing hypotension and risking cardiac arrest (Figure 2).

Local anaesthetic systemic toxicity can be prevented by reducing the rate of lignocaine injection and identifying risk factors within the preoperative period, particularly the extremes of age, pregnancy, renal disease, cardiac disease and patients with hepatic dysfunction.

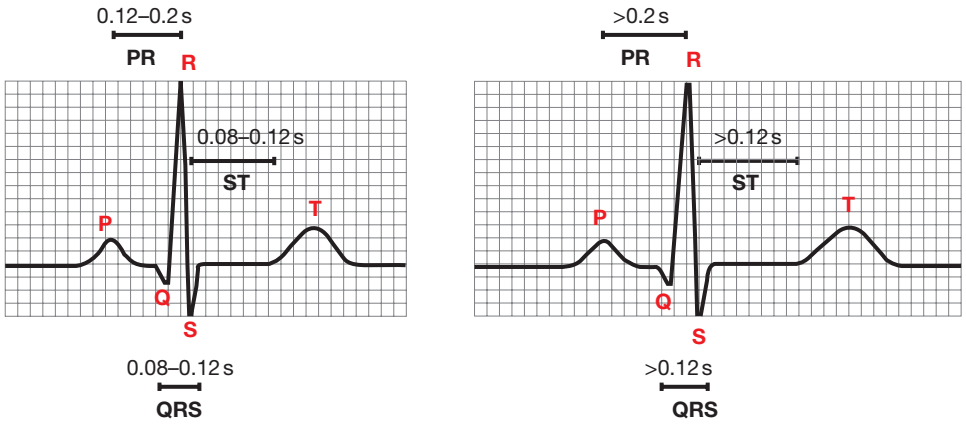

Figure 2. Electrocardiogram showing the cardiovascular toxicity signs associated with large doses of local anaesthetic agents, consisting of PR, QRS and ST interval prolongation.

The current antidote to local anaesthetic toxicity is lipid emulsion therapy. The exact mechanism of action is not fully elucidated, but it is highly successful in treating local anaesthetic toxicity (El-Boghdadly et al, 2018). Many speculate that intravascular lipids decrease the peripheral circulation of the local anaesthetic agent by creating a concentration gradient. This draws local anaesthetic from areas of high concentration within the brain and heart into a lipid sink (Karcioglu, 2017). An alternative theory postulates that the administration of intravascular lipids provides the myocardium with an immediate extracellular source of energy which counteracts local anaesthetic-associated inhibition of cardiac mitochondrial function and overcomes the bradyarrhythmia (Dogru et al, 2003).

Serious systemic reactions to adrenaline are rare, with few cases reported. The main concern is the administration of adrenaline to patients with cardiac disease, as adrenaline can cause transient tachycardic and hypertensive episodes (Little et al, 2018). These patients should be monitored perioperatively and reduced doses of adrenaline administered.

During hand surgery, white fingertips are common and occur when adrenaline is injected into the sheath and not the subcutaneous fat, causing the distal diffusion of adrenaline to the fingertips. Necrosis secondary to adrenaline injection is rare, with only one documented case of finger infarction in which lignocaine played a partial role (Ruiter et al, 2014). There have been many documented cases of accidentally high doses of adrenaline (1:1000) injections that have not caused finger loss or required phentolamine rescue (Fitzcharles-Bowe et al, 2007).

The reversal of complications secondary to adrenaline injection involves the administration of phentolamine, a competitive inhibitor of alpha-adrenergic receptors. Phentolamine was initially used for the management of phaeochromocytoma, with the aim of lowering a patient's blood pressure by intravenously administering a dose of 5 mg (Mamilla et al, 2019). In the rare case of a white finger that has not reperfused within 14 hours, treatment involves 1mg of phentolamine administered in 1ml or more of saline solution into the subcutaneous fat of the area with the most adrenaline-induced pallor. The phentolamine will remain within the extravascular compartment and, without causing hypotension, will restore the blood flow to the affected area within 1 hour and thus, prevent ischaemic neurapraxia and reperfusion pain (Tang et al, 2019).

Advantages and disadvantages

The practice of wide awake local anaesthesia no tourniquet surgery has advantages for patients, surgeons and healthcare institutions. The use of a local anaesthetic avoids the additional costs and risks associated with the use of general anaesthesia and preoperative screening. As such, this technique may prove more financially accessible to patients within a private healthcare setting and to those in developing countries. In many one stop clinics, patients can have a consultation and operation within the same visit, which is especially convenient for those having to drive long distances from rural settings.

The avoidance of general anaesthesia permits patients with multiple comorbidities to undergo operations more safely. This is especially true for people with diabetes, as they will not need to omit any antihyperglycaemic agents, and patients on long-term anticoagulation medication can safely continue their medication as satisfactory haemostasis will be achieved with adrenaline (Croutzet and Guinand, 2017). By using adrenaline to establish haemostasis, a proximal tourniquet is no longer required. The use of tourniquets has been associated with crush injury and increased postoperative pain, as well as venous stasis, blood pooling and an increased risk of thrombosis (Kukreja et al, 2018). Exsanguination and tourniquet application can make vessels more difficult to identify, and failure to cauterise breached vessels increases the risk of postoperative haematoma formation and associated wound complications (Lalonde, 2016). Another advantage of not using a tourniquet is that there is less pressure to perform the surgery in the shortest time possible, for example, if anomalous motor branches required dissection. Visualisation of epineural vessel filling, for example following a carpal tunnel decompression, is also possible when a tourniquet is not used. In a surgery using a tourniquet, visualisation of vessel filling would not be possible since the tourniquet would be released after wound closure (Iqbal et al, 2018).

In most cases of wide awake local anaesthesia no tourniquet surgery, patients can position themselves freely and, with the patient awake, surgeons are less likely to operate on the wrong limb. As the patient is able to talk to the surgeon, many can have their ideas explored and concerns reassured in real time, while receiving advice regarding postoperative care. Patients may observe an instant return of function in repaired structures which improves satisfaction, motivation and adherence to postoperative rehabilitation protocols.

By using a local anaesthetic agent, the patient is spared many postoperative side effects, including those associated with opiate use and sedation. The use of local anaesthetic further negates the need for observed postoperative recovery, reducing the duration of inpatient stay. This also reduces the social burden associated with undergoing operations, including the resuming of childcare and other responsibilities sooner, and lesser requirements for time taken off work to recover.

With the patient awake during surgery, the surgeon is able to observe the active movement of the limb which allows the assessment of tendon tensioning, glide and positioning. Common difficulties with repairing a tendon when the patient is under general anaesthesia include the setting of tension of the tendon across the repair site, as creating too much tension increases the risk of tendon rupture following the repair. However, during wide awake local anaesthesia no tourniquet surgery, the patient is able to move the limb and test the tension of the tendon during the surgery, allowing the surgeon to set and alter the tension after the repair, or transfer of a donor tendon. This not only makes the operation easier, but further reduces the risk of rupture and adhesions post-surgery. From an institutional perspective, the use of the wide awake local anaesthesia no tourniquet technique improves the cost-effectiveness of operative interventions within an ambulatory setting, as well as removing the need for comprehensive pre-assessment checks and anaesthetic fitness investigations (Wheelock et al, 2019). Perioperative patient education improves patient compliance with postoperative therapy and reduces the need for subsequent clinical follow ups. Operations may be completed with a reduced number of staff, usually one nurse, in non-operating theatre settings, as long as a sterile field can be maintained. This obviates the costs associated with full field sterility, which costs four times that required in wide awake local anaesthesia no tourniquet surgery (Kazmers et al, 2019). This leads to a higher turnover, increased efficiency, and an overall reduction in cost, especially costs associated with secondary operations following complications (Maliha et al, 2019). The use of wide awake local anaesthesia no tourniquet surgery and the ability to operate with field sterility has allowed twice as many carpal tunnel procedures to be performed in the same time (Lalonde, 2016).

Regional analgesia via nerve block confers many of the same benefits as the wide awake local anaesthesia no tourniquet technique, including excellent analgesia, the avoidance of general anaesthesia and its associated risks, and a reduced postoperative stay. However, while the wide awake local anaesthesia no tourniquet technique may be safely administered by the operating surgeon, the administration of regional analgesia requires an experienced anaesthetist, specialist equipment and invariably longer induction times, ultimately reducing patient turnover and increasing the overall cost. Some clinicians advocate for additional sedation and analgesia to alleviate patient distress and discomfort while establishing the motor block. However, this may hamper postoperative discharge, as patients are retained for a monitoring period and can be inconvenienced by having to organise alternative transport home. As with general anaesthesia, when using regional analgesia a tourniquet must be applied to enable adequate haemostasis and, despite being awake, the ability to test tendon tension is limited because of the associated regional analgesia motor block. A meta-analysis by Evangelista et al (2019) revealed that regional analgesia had shorter operating times compared to wide awake local anaesthesia no tourniquet surgery, but had higher postoperative pain scores.

Disadvantages of wide awake local anaesthesia no tourniquet surgery include the proportionally shorter duration of local anaesthetic action as compared to a regional block. As such, the wide awake local anaesthesia no tourniquet technique may only be appropriate for procedures which last under 2 hours. It is also important to bear in mind the time taken for the haemostatic effect to develop after injecting the local anaesthetic, usually 20 minutes, which may have implications for the organisation of cases and running of theatres. Invariably the local injection of large quantities of fluid will distort local anatomy

and the surgeon must learn to work within a surgical field that can be wetter than when using a tourniquet. Surgeons may also choose to avoid the wide awake local anaesthesia no tourniquet technique when a significant amount of the surgery involves bone.

It is important to bear in mind contraindications to the use of a wide awake local anaesthesia no tourniquet technique, including a documented allergy or previous reaction to local anaesthetic. One should also be cautious when operating on patients with peripheral circulation compromise, as this could be associated with a previous vascular injury, atherosclerosis, Buerger's disease, or other rheumatic disease. Adrenaline can have central effects on cardiac or psychological function. Anxious and non-compliant patients may struggle with being awake throughout the procedure and may be better suited for surgery under general anaesthesia. Studies reporting cases where a surgery was converted from a wide awake local anaesthesia no tourniquet technique to general anaesthesia are limited (Ahmad et al, 2020; Turcotte et al, 2020; Yi et al, 2020), with only one study reporting two cases requiring conversion (Tahir et al, 2020). This rate is comparably better than the rate for regional analgesia, as the study further reported four cases using Bier block that required conversion to general anaesthesia. Despite the minimal data on conversion rates in wide awake local anaesthesia no tourniquet surgery, this early figure can preliminarily show comparable and possibly improved rates when compared to regional analgesia.

Criteria for wide awake local anaesthesia no tourniquet surgery

Adult patients with no documented history of hypersensitivity to lignocaine nor vascular compromise. The procedure must require a superficial approach, where a field block is achieved to operate on a single digit or fracture at a non-infected site. The procedure must have an estimated operation time of less than 2 hours.

Current uses

Table 1 lists all procedures which are routinely performed using the wide awake local anaesthesia no tourniquet technique.

Applications from case reports

Table 2 lists procedures which are not routinely performed using the wide awake local anaesthesia no tourniquet technique. However, cases where the wide awake local anaesthesia no tourniquet technique has been used for these procedures have been reported within the literature.

Standard applications of the wide awake local anaesthesia no tourniquet technique have been adapted from Lalonde (2016), focusing on procedures within the field of hand surgery. The potential applications of wide awake local anaesthesia no tourniquet surgery taken from case reports have been adapted from other authors (Wong et al, 2017; Huang et al, 2018; Ahmad et al, 2020; Bilgetekin et al, 2020; Xu et al, 2021).

The future

The various benefits of the wide awake local anaesthesia no tourniquet technique will lead it to become the gold standard approach for many hand operations. The reduced risk of tendon rupture, tenolysis and secondary surgery, in combination with the active movement aspect seen within tendon repairs, will promote the use of wide awake surgery for most tendon surgeries.

There are opportunities to explore the use of wide awake local anaesthesia no tourniquet surgery within the acute management of digital trauma and other orthopaedic subspecialties. Despite the limited data on the scope for the use of the wide awake local anaesthesia no tourniquet technique in foot and ankle operations, early studies have demonstrated similar satisfactory results in the management of simple injuries (Poggetti et al, 2018; Li et al, 2019; Bilgetekin et al, 2020).

Table 1. Procedures in hand surgery that are routinely performed using the wide awake local anaesthesia no tourniquet technique

Amputation	Finger and ray amputation
Nerve decompression	■ Carpal tunnel decompression of the median nerve ■ Cubital tunnel decompression of the ulnar nerve ■ Lacertus syndrome: median nerve release at the elbow
Tendon decompression	■ Trigger finger ■ De Quervain release
Dupuytren's contracture and soft tissue excision	■ Dupuytren's contracture ■ Flexor sheath ganglion ■ Small soft tissue operations
Arthritis surgery	■ Arthroplasty of the proximal interphalangeal joint ■ Trapeziectomy, with or without ligament reconstruction, for thumb basal joint arthritis ■ Thumb metacarpophalangeal joint fusion and ulnar collateral ligament repair ■ Proximal interphalangeal joint fusion
Wrist surgery	■ Wrist arthroscopy ■ Open triangular fibrocartilage complex repair
Lacerated tendons and tenolysis	■ Flexor tendon repair of the finger ■ Flexor tendon repair of the hand ■ Flexor tendon repair of the forearm ■ Extensor tendon repair of the hand ■ Extensor tendon repair of the forearm ■ Tenolysis
Tendon transfers	
Lacerated nerves	
Fractures	■ Finger fractures ■ Reduction and internal fixation of metacarpal fractures ■ Distal radius fractures ■ Olecranon fractures
Complex reconstructions in hand surgery	■ Digital revascularisation and replantation ■ Pedicled skin flap ■ Random skin flap

Table 2. Procedures that have traditionally been performed under general anaesthesia that have the potential to be performed wide awake and under local anaesthesia

Clavicle fracture fixation		
Foot and ankle surgery	Fractures: open reduction and internal or percutaneous fixation	■ Medial malleolus fracture ■ Lateral malleolus fracture ■ Proximal phalanx fracture
	Lisfranc dislocation	
	Lacerated tendons and ligaments	■ Achilles' tendon rupture: open and percutaneous ■ Deltoid ligament: open repair ■ Syndesmosis injury: screw placement
	Distal fibula hardware removal	

Key points

- The practice of wide awake local anaesthesia no tourniquet surgery has advantages for patients, surgeons and healthcare institutions through increasing safety, efficacy and reducing costs.
- The conferred benefits of wide awake local anaesthesia no tourniquet surgery may soon make it the gold standard within hand surgery, superseding general anaesthesia.
- Opportunities persist to explore the role of wide awake local anaesthesia no tourniquet surgery within other orthopaedic subspecialties.
- Despite being a rare occurrence, systemic local anaesthetic toxicity presents more commonly with CNS effects than cardiovascular ones but is reversible through the administration of lipid emulsion therapy.
- Necrosis secondary to adrenaline injection is rare, and reversal of a white fingertip is possible with the use of phentolamine, an alpha-adrenergic receptor inhibitor.

The numerous cost advantages, increased resource efficiency and increased accessibility for patients with multiple comorbidities, will further lead to an organisational push for the use of wide awake local anaesthesia no tourniquet surgery, within both struggling public healthcare environments and insurance-based private sectors. Owing to the precautions taken to minimise intraoperative exposure to aerosol-generating procedures and reduce the duration of inpatient stay, important points during the current COVID-19 climate, using the wide awake local anaesthesia no tourniquet technique provides the opportunity to deliver care, even in times of difficulty accessing theatres and anaesthetic support.

Author details

[1]Department of Vascular Surgery, Royal Liverpool & Broadgreen Hospitals NHS Trust, Liverpool University Hospitals NHS Foundation Trust, Liverpool, UK

[2]Department of Trauma and Orthopaedics, East Lancashire Hospitals NHS Trust, Blackburn, UK

Conflicts of interest

The authors declare that there are no conflicts of interest.

References

Ahmad AA, Ubaidah Mustapa Kamal MA, Ruslan SR, Abdullah S, Ahmad AR. Plating of clavicle fracture using the wide-awake technique. J Shoulder Elbow Surg. 2020;29(11):2319–2325. https://doi.org/10.1016/j.jse.2020.03.003

Azar FM, Canale ST, Beatty JH (eds). Campbell's operative orthopaedics. 14th edn. Philadelphia (PA): Elsevier; 2020

Bilgetekin YG, Kuzucu Y, Öztürk A et al. The use of the wide-awake local anesthesia no tourniquet technique in foot and ankle injuries. Foot Ankle Surg. 2020;27(5):535–538. https://doi.org/10.1016/j.fas.2020.07.002

Croutzet P, Guinand R. Maintaining anticoagulant treatment in hand surgery – a review of 63 procedures. Hand Surg Rehabil. 2017;36(6):428. https://doi.org/10.1016/j.hansur.2017.10.008

Denkler K. A comprehensive review of epinephrine in the finger: to do or not to do. Plast Reconstr Surg. 2001;108(1):114–124. https://doi.org/10.1097/00006534-200107000-00017

Dogru K, Duygulu F, Yildiz K et al. Hemodynamic and blockade effects of high/low epinephrine doses during axillary brachial plexus blockade with lidocaine 1.5%: a randomized, double-blinded study. Reg Anesth Pain Med. 2003;28(5):401–405. https://doi.org/10.1016/s1098-7339(03)00225-6

El-Boghdadly K, Pawa A, Chin KJ. Local anesthetic systemic toxicity: current perspectives. Local Reg Anesth. 2018;11:35–44. https://doi.org/10.2147/LRA.S154512

Evangelista TMP, Pua JHC, Evangelista-Huber MTP. Wide-Awake Local Anesthesia No Tourniquet (WALANT) versus local or intravenous regional anesthesia with tourniquet in atraumatic hand cases in orthopedics: a systematic review and meta-analysis. J Hand Surg Asian Pac Vol. 2019;24(4):469–476. https://doi.org/10.1142/S2424835519500619

Fitzcharles-Bowe C, Denkler K, Lalonde D. Finger injection with high-dose (1:1,000) epinephrine: does it cause finger necrosis and should it be treated? Hand. 2007;2(1):5–11. https://doi.org/10.1007/s11552-006-9012-4

Food and Drug Administration. Warning-procaine solution. JAMA. 1948;138(599)

Hameln Pharma Ltd. Adrenaline (Epinephrine) injection BP 1 in 1000. 2020. https://www.medicines.org.uk/emc/product/6284/#gref (accessed 18 October 2021)

Huang Y-C, Hsu C-J, Renn J-H et al. WALANT for distal radius fracture: open reduction with plating fixation via wide-awake local anesthesia with no tourniquet. J Orthop Surg Res. 2018;13(1):195. https://doi.org/10.1186/s13018-018-0903-1

Iqbal HJ, Doorgakant A, Rehmatullah NNT et al. Pain and outcomes of carpal tunnel release under local anaesthetic with or without a tourniquet: a randomized controlled trial. J Hand Surg Eur Vol. 2018;43(8):808–812. https://doi.org/10.1177/1753193418778999

Karcioglu O. Use of lipid emulsion therapy in local anesthetic overdose. Saudi Med J. 2017;38(10):985–993. https://doi.org/10.15537/smj.2017.10.20525

Kattan S, Lee S-M, Hersh EV, Karabucak B. Do buffered local anesthetics provide more successful anesthesia than nonbuffered solutions in patients with pulpally involved teeth requiring dental therapy?: a systematic review. J Am Dent Assoc. 2019;150(3):165–177. https://doi.org/10.1016/j.adaj.2018.11.007

Kazmers NH, Stephens AR, Presson AP, Yu Z, Tyser AR. Cost implications of varying the surgical setting and anesthesia type for trigger finger release surgery. Plast Reconstr Surg Glob Open. 2019;7(5):e2231. https://doi.org/10.1097/GOX.0000000000002231

Kukreja P, Lehtonen E, Pinto MC et al. Postoperative tourniquet pain in patients undergoing foot and ankle surgery. Cureus. 2018;10(12):e3678. https://doi.org/10.7759/cureus.3678

Lalonde D, Bell M, Benoit P et al. A multicenter prospective study of 3,110 consecutive cases of elective epinephrine use in the fingers and hand: the Dalhousie Project clinical phase. J Hand Surg Am. 2005;30(5):1061–1067. https://doi.org/10.1016/j.jhsa.2005.05.006

Lalonde DH. Wide awake hand surgery. Stuttgart: Georg Thieme Verlag; 2016

Li Y-S, Chen C-Y, Lin K-C et al. Open reduction and internal fixation of ankle fracture using wide-awake local anaesthesia no tourniquet technique. Injury. 2019;50(4):990–994. https://doi.org/10.1016/j.injury.2019.03.011

Little JW, Miller CS, Rhodus NL, Little JW. Little and Falace's dental management of the medically compromised patient. 2018. http://www.clinicalkey.com/dura/browse/bookChapter/3-s2.0-C20150014228 (accessed 18 October 2021)

Maliha SG, Cohen O, Jacoby A, Sharma S. A cost and efficiency analysis of the WALANT technique for the management of trigger finger in a procedure room of a Major City Hospital. Plast Reconstr Surg Glob Open. 2019;7(11):e2509. https://doi.org/10.1097/GOX.0000000000002509

Mamilla D, Araque K, Brofferio A et al. Postoperative management in patients with pheochromocytoma and paraganglioma. Cancers. 2019;11(7):936. https://doi.org/10.3390/cancers11070936

Poggetti A, Del Chiaro A, Nicastro M et al. A local anesthesia without tourniquet for distal fibula hardware removal after open reduction and internal fixation: the safe use of epinephrine in the foot. A randomized clinical study. J Biol Regul Homeost Agents. 2018;32(6 Suppl. 1):57–63

Ruiter T, Harter T, Miladore N, Neafus A, Kasdan M. Finger amputation after injection with lidocaine and epinephrine. Eplasty. 2014;14:ic43

Silva Neto OBD, Costa CFPA, Veloso FS, Kassar SB, Sampaio DL. Efeitos do uso de vasoconstritores no bloqueio de nervos digitais: revisão sistemática com metanálise. Rev Col Bras Cir. 2020;46(6):e20192269. https://doi.org/10.1590/0100-6991e-20192269

Swain A, Nag DS, Sahu S, Samaddar DP. Adjuvants to local anesthetics: current understanding and future trends. World J Clin Cases. 2017;5(8):307–323. https://doi.org/10.12998/wjcc.v5.i8.307

Tahir M, Chaudhry EA, Zaffar Z et al. Fixation of distal radius fractures using wide-awake local anaesthesia with no tourniquet (WALANT) technique: a randomized control trial of a cost-effective and resource-friendly procedure. Bone Joint Res. 2020;9(7):429–439. https://doi.org/10.1302/2046-3758.97.BJR-2019-0315.R1

Tang JB, Xing SG, Ayhan E, Hediger S, Huang S. Impact of wide-awake local anesthesia no tourniquet on departmental settings, cost, patient and surgeon satisfaction, and beyond. Hand Clin. 2019;35(1):29–34. https://doi.org/10.1016/j.hcl.2018.08.012

Taylor A, McLeod G. Basic pharmacology of local anaesthetics. BJA Educ. 2020;20(2):34–41. https://doi.org/10.1016/j.bjae.2019.10.002

Thomson CJ, Lalonde DH, Denkler KA, Feicht AJ. A Critical Look at the Evidence for and against Elective Epinephrine Use in the Finger. Plastic and Reconstructive Surgery. 2007;119(1):260-266. https://doi:10.1097/01.prs.0000237039.71227.11

Turcotte JJ, Petre BM, Jones CM, Gelfand JM. Maintaining access to orthopaedic surgery during periods of operating room resource constraint: expanded use of wide-awake surgery during the COVID-19 pandemic. J Am Acad Orthop Surg Glob Res Rev. 2020;4(12):e20.00100. https://doi.org/10.5435/JAAOSGlobal-D-20-00100

Wheelock M, Petropolis C, Lalonde DH. The Canadian model for instituting wide-awake hand surgery in our hospitals. Hand Clin. 2019;35(1):21–27. https://doi.org/10.1016/j.hcl.2018.08.001

Wong J, Lin C, Chang N et al. Digital revascularization and replantation using the wide-awake hand surgery technique. J Hand Surg Eur Vol. 2017;42(6):621–625. https://doi.org/10.1177/1753193417703516

Xu J, Yin L, Cao S et al. Application of WALANT technique for repairing finger skin defect with a random skin flap. J Orthop Surg Res. 2021;16(1):164. https://doi.org/10.1186/s13018-021-02319-3

Yi LM, Ahmad AA, Ruslan SR, Abdullah S, Ahmad AR. Plating distal radius fractures using Wide-Awake Local Anesthesia No Tourniquet (WALANT) versus general anesthesia: a cohort study. J Hand Surg Glob Online. 2020;2(6):331–338. https://doi.org/10.1016/j.jhsg.2020.09.003