Chapter 25
Anesthesia of the injured hand

James Clarkson, MD
Yorell Manon-Matos, MD

Introduction

This chapter will present the authors' experience of managing hand trauma in the office and emergency room setting, using Wide Awake Local Anesthesia No Tourniquet (WALANT) with the additional use of Virtual Reality (VR). We have termed the additional use of VR with WALANT as Wide Awake VR (WAVR). High brachial plexus nerve blocks are well described in other texts. The Bier's block is not suitable for the office environment and will not be covered here.

Injuries to the hands and fingers represent a considerable proportion of emergency room visits. When the downstream loss of occupation is taken into account they are also the most expensive[1]. Furthermore, hand trauma volumes may be unpredictable and can be interruptive to the normal flow of an elective practice. Health systems have long recognized the need to generate efficient treatment pathways for hand trauma management to mitigate its impact on healthcare resource allocation [2,3,4].

When managing a hand injury anesthesia may be delivered via general anesthesia (GA) or sedation with either regional nerve block or locally delivered tumescence of local anesthetic agents. Local anesthetic nerve block and local tumescence may also be provided without sedation or GA. The location of care is also optional, and may considerably affect its timely and convenient delivery. Because lidocaine does not require monitoring or ventilation support the location of care may be independent of the main operating room. Many procedures may be offered in a clean environment using simple field sterility alone such as the office and emergency room environment [5]. More complex surgery will still be offered in the operating room, however, increasingly complex hand trauma care that is delivered under local anesthesia outside the operating room has gained acceptance following the popularisation of Wide Awake Local Anesthesia with no Tourniquet (WALANT) [2,6,7,8,9,10].

Published examples of WALANT used for Hand trauma	Increasing complexity and severity of upper limb trauma At Michigan State we offer 1-10 in office
P. Clarkson 1950	1. Simple lacerations
	2. Complex lacerations involving deep structures
	3. Skin grafting
	4. Finger amputation revision
Xing et al 2019	5. Local hand flaps
Mckee/Lalonde 2017	6. Open reduction irreducible hand dislocations
Gregory/Lalonde 2014	7. Closed or open reductions and K wires
	8. Repair hand tendon extensor.
Lalonde 2009	9. Repair hand tendon flexor
	10. Repair of major wrist multi tendon and nerve injury
	11. Phalanx and metacarpal ORIF with plates and screws
Hagarty/Lalonde 2009	12. Wrist arthroscopy
Ahmad et al 2017	13. ORIF long forearm bones
	14. Flexor tendon irrigation and deep space or joint infection
Wong et al 2017	15. Microvascular repair
	16. High-pressure injection injuries
	17. Extensive soft tissue loss
	18. The mangled hand and wrist
	19. Hand burns

Table1. Increasing use of WALANT for hand trauma [2,6,7,8,9,10]

The authors of this chapter advocate WALANT for hand trauma because it provides the surgeon with an independent means of addressing the majority of hand trauma pathologies without resorting to the main hospital operating room with its attendant treatment delays, expense, and anesthetic risks.

This is not a new observation, and by the middle of the 20th century hand surgeons were attempting to resolve large volumes of hand trauma in a similar fashion. It is with a sense of historical irony that the authors observe

that a similar policy was delivered in Guy's hospital Accident Department in 1950, in their efforts to streamline hand trauma care[2]. Have we really come so far?

P.W Clarkson, "*Wide Awake*" hand trauma without epinephrine, Guys Hospital Accident Department 1950

J.H.W Clarkson WAVR Michigan State University Hand Trauma 2020

Figure 1.

Mechanism of action for local anesthetics

Local anesthetic Amides and Esters are based on mid-19th-century pharmacology derived from Cocaine and refined over the subsequent hundred years. There are no alternatives in use. The two commonly used by hand surgeons are lidocaine, with shorter duration and swifter onset, and bupivacaine, which is slower to take effect, longer-lasting and more cardiac sensitive. The latter is less suitable for office and non-monitored environments due to the risk of cardiac dysrhythmia but is popular in the operating room providing up to 8 hours of postoperative anesthesia. Bupivacaine is also produced as a liposomal emulsion for slow release over 3-5 days[11].

Local anesthetic action is mediated via inhibition of voltage-sensitive Na+ channels, thus blocking the nerve action potential from propagating nociceptive stimulus to the brain. For local anesthesia to work, it must be water-soluble to be carried by the extracellular matrix and thus penetrate the surrounding tissue and lipophilic to penetrate the myelin sheath and interact with the axolemma. To facilitate these two properties local anesthetic agents have both hydrophilic and lipophilic components.

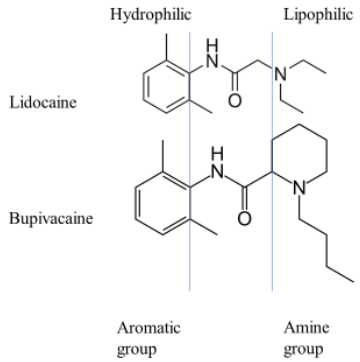


Figure 2. Chemical structure of local anesthetics

Infected hands do not tolerate tumescent technique well when already swollen and the hyperemia will quickly washout the local anesthetic. Furthermore, local anesthetics are weak bases and will become ionized by the acidic environment encountered in infected tissue. The ionized form does not cross the Axollema well, and efficacy is thus reduced in the presence of inflammation and infection.

Esters and Amides

The earliest local anesthetics based on Cocaine were Esters, which are broken down by pseudocholinesterase leading the production of para-amino-benzoic acid (PABA), a known stimulus for hypersensitivity reactions.
Amides, first developed in the 1940s, have a swifter onset and much lower hypersensitivity risk. Amides, however, retain the rare potential to produce allergic reactions, usually due to the preservative methylparaben, which may breakdown to PABA. For patients who are allergic to esters a preservative-free amide local anesthetic should be used[12]. Caution must be taken if they are used with certain medications such as Erythromycin and other macrolides, HIV protease inhibitors, antifungal agents such as itraconazole calcium channel blockers.

One easy way to identify an Amide vs an Esther is weather the name has 2 “i”s. If true, it is an Amide. The student pitfall is the use of the trade name “Marcaine” which is really Bupivacaine with 2 “i”s, and hence an Amide not an Ester.

Esters	
	Cocaine
	Procaine
	Tetracaine
Amides	
	Lidocaine
	Bupivacaine
	Prilocaine
	Ropivacaine
	Levobupivacaine

Table 2 Esters and Amides

Vasovagal response

Individuals may develop a vasovagal response at the time of a needle puncture or any perceived noxious stimulus such as a cast change. In our practice, we inject with the patient sitting up but can quickly lie them back should they report nausea or faintness. Others recommend injections be performed in all patients lying down. During a vasovagal reaction once lying down the patient’s legs may be elevated to increase circulation to the brain[13,14].

Local anesthetic toxicity and resuscitation

Bodyweight is commonly used to estimate the risk of systemic toxicity, the plasma levels should not exceed the following:

Lidocaine	• 5 mcg/mL
Bupivacaine	• 1.5 mcg/mL

Table 3. Maximum safe plasma concentration

However, injection site, pregnancy, the use of epinephrine and patient-related conditions such as cardiac, renal or hepatic dysfunction are more important determinants of local anesthetic plasma levels [15]. Classically, the safe dose of lidocaine without epinephrine is 4mg/kg and when combined with epinephrine this may increase to 7mg/kg. For every cc of 1% lidocaine, there is 10mg of lidocaine, so for a 70kg adult, you can expect to inject around 50cc of 1% lidocaine with epinephrine. This is based on estimates from the 1950s and is very conservative, allowing for considerable leeway [16]. More recent estimates are up to 5 times as much, 35mg/kg [17]. This, however, makes the assumption of third space sequestration and up to a third of the solution being removed by liposuction [18]. We do not advise using a higher dose than 7mg/kg when operating away from a hospital operating room setting where the complications of local anesthetic toxicity may be optimally managed.

Lidocaine toxicity will classically present with perioral numbness, facial tingling and a metallic taste in the mouth. Late effects at higher doses include tonic-clonic seizures, followed by ventricular fibrillation and cardiac arrest. Bupivacaine is injected with or without epinephrine at the same dose of 2-3 mg/kg. Because its duration of action exceeds the duration of epinephrine, no significant dose increase is recommended. This is not the preferred agent for WALANT surgery due to its myocardial affinity that may cause fibrillation before central nervous symptoms present. Bupivacaine can produce ventricular arrhythmias heralded by prolongation of PR and widening of the QRS.
In the event of cardiac arrest or seizure, ACLS protocols must be followed with prompt airway management, intravenous fluid resuscitation, and defibrillation. The use of vasopressors to support coronary perfusion may be needed. Amiodarone should be chosen over lidocaine to manage arrhythmias. Seizures should be managed with benzodiazepines [15]. Electromechanical dissociation may be rescued using lipid emulsion [19]. Lipid emulsion

(Intralipid®10%) may reverse local anesthetic toxicity by extracting local lipophilic from plasma, or tissues. The regimens used in these cases consisted of bolus doses of 1.2-2 mL/kg followed by continuous infusions of 0.25-0.5 mL/kg/min. The use of lipid emulsion has been described in cases of local and systemic toxicity, seizures, EKG abnormalities, and cardiac arrest [20].

Bicarbonate

Local anesthetic agents are mildly acidic with a pH value ranging from 3.3 to 5.5. This acidity may contribute to the injection pain. Bicarbonate has been shown by meta-analysis to significantly reduce pain [21].

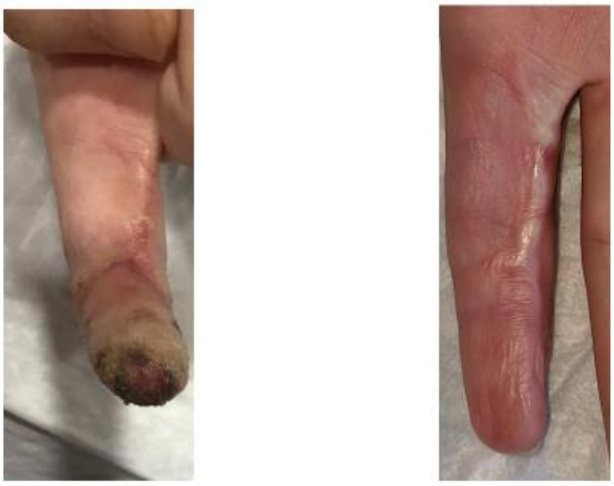
Epinephrine

Epinephrine may be added to local anesthetic to counteract the vasodilation otherwise caused by vessel wall paralysis [22]. Many patients will sense the presence of epinephrine, symptoms will include fearfulness, shaking, and palpitations. For patients with severe cardiovascular disease, it may be prudent to use a reduced dose and to monitor their care in a hospital environment, although there are series reporting its safe use [23, 24]. The use of epinephrine should be used with caution when patients are taking Tricyclic antidepressants and Serotonin-Norepinephrine reuptake inhibitors [25].

The Epinephrine debate

The reintroduction of the use of epinephrine in the hand represents a paradigm shift since the early thousands. 20th-century dogma dictated that epinephrine was "forbidden because of the risk of digital ischemia due to thrombosis of the digital vessels" [26.] In keeping with Sterling Bunnel's position "can a jeweler repair a watch in a pool of ink", hand surgery is most easily provided in a bloodless field [26]. By reintroducing epinephrine back into hand surgery we can reduce our dependence on a tourniquet. Once the pain of tourniquet dependant surgery is removed the need for sedation and general anesthesia is significantly reduced. The use of epinephrine in hand surgery is now widely considered safe following multiple publications over the past 22 years [27, 28, 29, 30].

However, a cautious approach is still necessary. One of the authors has experienced a case of digital tip necrosis with the use of epinephrine in a finger following a crush injury 7 weeks prior. This was fully salvaged using Hyperbaric oxygen (unpublished personal communication JHW Clarkson).



Epinephrine induced tip ischemia 7 weeks post crush injury

The fingertip salvaged by Hyperbaric oxygen Therapy

Figure 3. Epinephrine induced ischemic necrosis

There is one other case report of this phenomenon in the recent literature [31]. Another recent study demonstrated an increased infection rate in 999 prospective trigger finger releases [32]. Phentolamine should be available to reverse epinephrine induced ischemia should it develop or when critical blood flow monitoring is desired [31].

Hence, when there is a perceived risk to blood flow, for example, digital fibrosis following crush injuries or systemic diseases such as scleroderma, epinephrine may still be avoided. For surgeons using epinephrine, dusky

or blanched fingertips at the end of the case are a common post-operative finding, implying that the surgeon needs to have no doubt in the primary blood supply if they are going to be able to tolerate this observation. It is the authors' opinion that WALANT performed with epinephrine should only be practiced after considerable experience using epinephrine in the main operating room before being undertaken in the emergency room or office setting.

The bloodless field enables WALANT surgery
Avoidance of sedation and general anesthesia
Application in the emergency room and office setting
Increased access for patients and surgeons increases the speed to definitive treatment
Reduced out of hours surgery improves the quality of life for the surgeon
Safe for patients with significant comorbidities
No need to wait 6-8 hours from the last meal
Take regular medication
Decreased costs and staffing, no post-operative anesthesia recovery
Decreased anesthesia risks
No cautery
No "let down" bleeding after tourniquet release reduces surgical time
Avoids tourniquet for patients with lymphedema
Decreased sterile services waste
Improved patient education
Direct functional observation of repaired parts in motion
Longer action of lidocaine
Hydrodissection facilities dissection

Table 4. Advantages of epinephrine and WALANT for hand trauma

Cardiac tachycardia and anxiety response
Syncope response
Reported increased risk of infection [32]
May potentiates pre-existing ischemic pathology [31,(JHW Clarkson personal communication)]
Difficult to assess primary vascular insufficiency following dissection

Table 5. Disadvantages of epinephrine and WALANT

WALANT technique

We are fortunate to have a rich literature on WALANT from Dr Lalonde, which combined with our experience is summarized below [14].

Equipment
10 cc syringe (contains 11cc!)
27-gauge needle
10cc 1% lidocaine with 1:100,000 epinephrine 9 cc buffered with 1cc of 8.4% bicarbonate
Tumescence
Primarily WALANT technique is a process of locally and slowly delivered tumescence of 1% lidocaine and 1:100,000 epinephrine with Bicarbonate with and optional local nerve block.
Tips
Warm refrigerated solutions
Countdown verbally from 3 before injection
Pinch the skin at the moment of injection
Inject slowly with a stable needle
Inject 0.5 -1 cc 1% lidocaine with 1:100,000 epinephrine buffered with 8.4% bicarbonate with the needle at 90º to the skin, then rub the tumescence for 30 seconds.
Inject the rest over 60 seconds with the needle at a more tangent angle to the skin, keep the needle tip within the area of tumescence and work outwards, slowly.
It is reasonable to inject more than you think you need.
Wait 20-30 mins, don't rush.

Table 6. WALANT technique

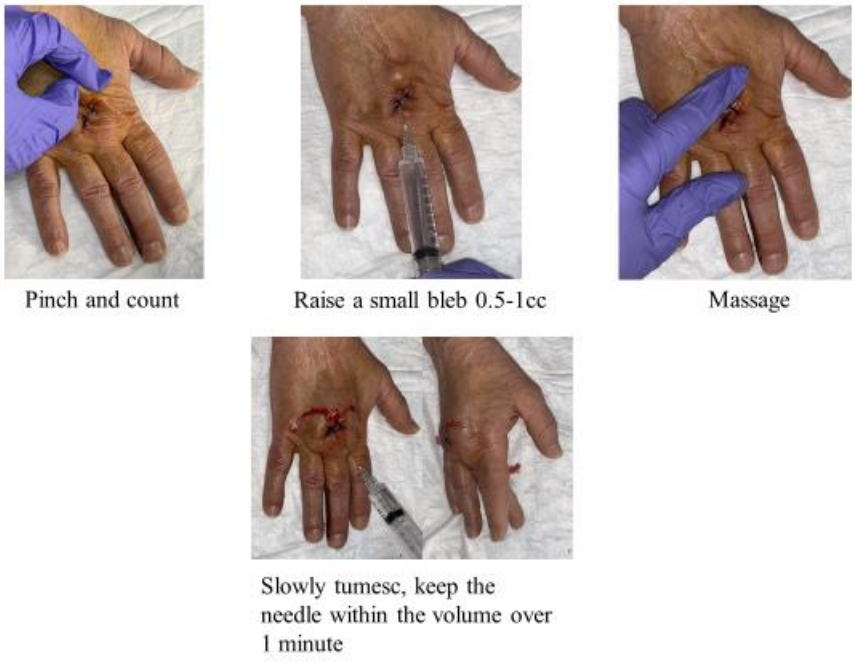


Figure 4. Injecting tumescent local anesthetic.

Exception to the tumescent rule

The exception to this principle is the digital block. It is important to avoid more than 2-3 cc 1% lidocaine with 1:100,000 epinephrine buffered with 8.4% bicarbonate of tumescence between the digital bundles to avoid compression of the vessels. Inject with the needle at 90º to the skin. To achieve dorsal anesthesia proximal to the proximal phalangeal joint, a dorsal injection of 3 cc 1% lidocaine with 1:100,000 epinephrine buffered with 8.4% bicarbonate is also required. A local ring tourniquet is well tolerated.

Figure 5. Digital block with 2-3cc only between the vessels.

Paradoxical bleeding

Vasoconstriction and a bloodless field may only be achieved where the epinephrine is present in the interstitium around the capillary bed. Paradoxically, paralysis of digital vessel sympathetic fibers by proximal

lidocaine injection may create increased distal bleeding despite the presence of epinephrine in the proximal site. Highly fibrotic tissue may also display similar vasodilation due to the failure of the epinephrine to perfuse throughout the field, generating greater bleeding. A good example of this is encountered during elective tenolysis in a densely fibrotic stiff hand.

Infection

An infected, inflamed environment will ionize lidocaine and hyperemia will wash it away, causing the efficacy to fall. Perform tumescence proximal to and surrounding the inflamed tissue,

Larger volume local anesthesia

To perform WALANT on large volumes, such as a forearm exploration you may dilute 50 cc 1% lidocaine with 1:100,000 epinephrine buffered with 8.4% bicarbonate up to 200cc with saline and it will retain acceptable efficacy but for a shorter duration [14]. Large forearm regions may be tumesced by blunt cannula once the entry point is first tumesced with a 27-gauge needle.

Metacarpal K-wire blocks

Metacarpal blocks may be achieved with a combination of local tumescence around the fractured metacarpal and planned wire entry points in addition to a regional wrist block to ensure that the K wire is not felt as it drives into adjacent bones. Cover dorsal and volar territories.

Nerve blocks at the wrist:

Wrist Blocks may be delivered with or without ultrasound guidance. It is important not to inject if the patient can feel an electric sensation indicating that the needle tip is in the nerve

Superficial Radial Nerve block

Injection of 5-10cc of 1% lidocaine with 1:100,000 epinephrine buffered with 8.4% bicarbonate over the radial styloid and anatomic snuffbox just beyond the divisions of the superficial radial nerve. Frequent aspiration is important to avoid accidental injection of the cephalic vein.

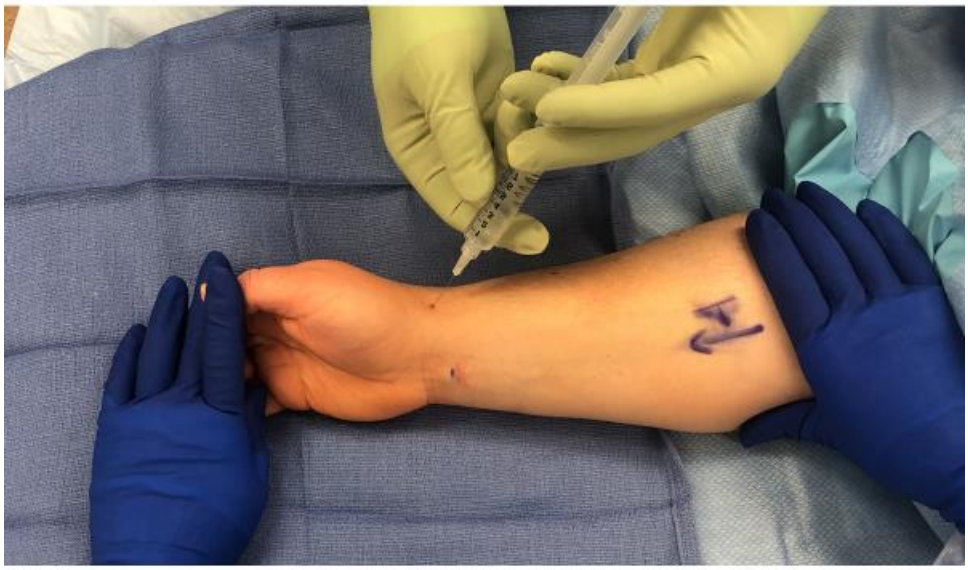


Figure 6. Superficial radial nerve block.

Median Nerve block

Injection with 10 cc of 1% lidocaine with 1:100,000 epinephrine buffered with 8.4% bicarbonate; care must be taken to avoid intraneural injection.

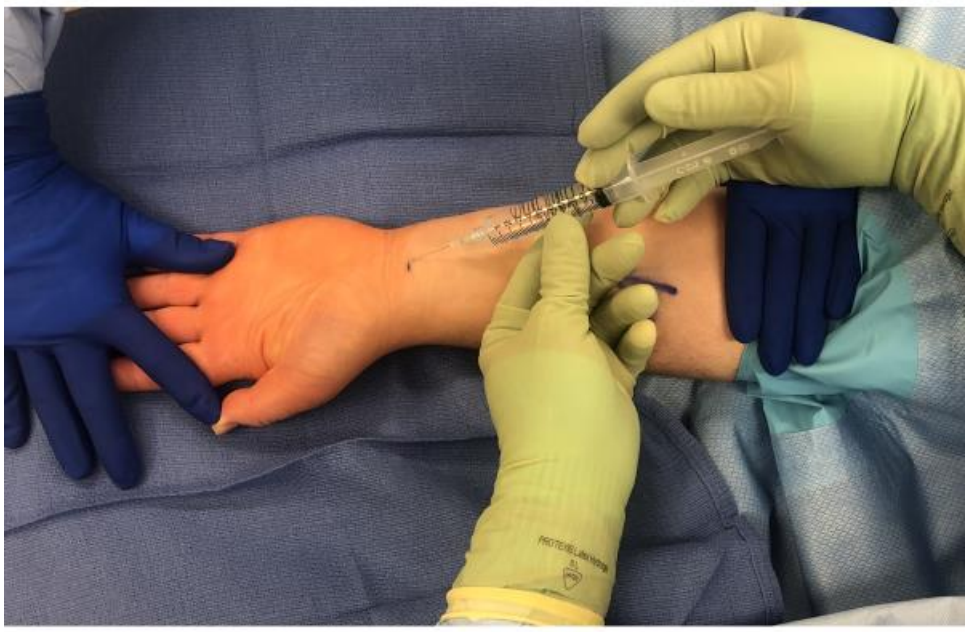


Figure 7. Median nerve block.

Ulnar Nerve block

Inject from either side of the flexor carpi ulnaris tendon 1-2 cm proximal to the pisiform. Deliver 5-10cc 1% lidocaine with 1:100,000 epinephrine buffered with 8.4% bicarbonate, taking care to aspirate to avoid intravascular injection of the ulnar artery. Deliver a further 5 cc of 1% lidocaine with 1:100,000 epinephrine buffered with 8.4% bicarbonate at the ulnar styloid dorsally to catch the dorsal branch.

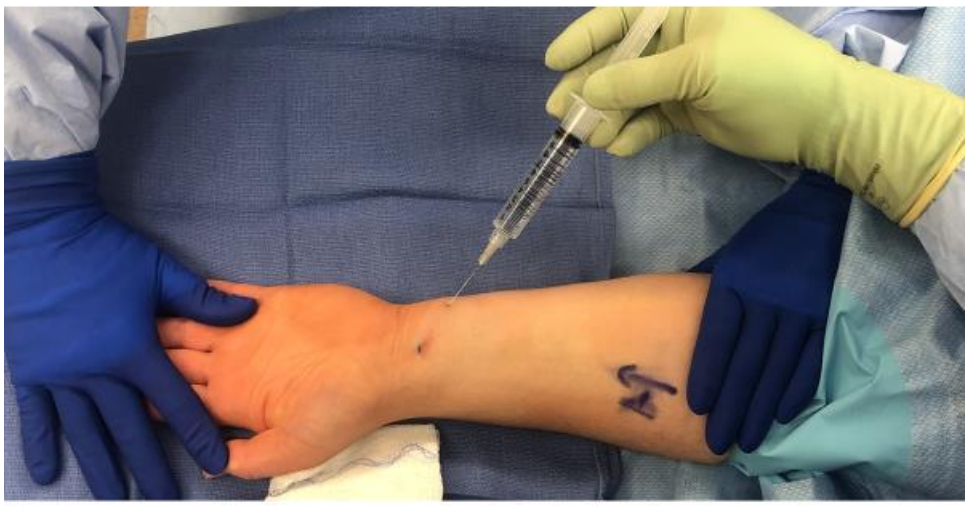


Figure 8. Ulnar nerve block.

Wide Awake Virtual Reality (WAVR)

Virtual Reality worn by patients is a nascent technology being applied to multiple clinical environments. These include pediatric burns dressings changes, dental procedures, cystoscopy and chemotherapy administration and inpatient invasive procedures [33-55]. In addition, psychological medicine has developed VR exposure therapies to manage common problems such as phobias [56], chronic pain [57] and addiction [58].

In 1962 Patrick Clarkson observed that "operations for most hand wounds may be performed under local anesthesia. Children and apprehensive adults are best treated under general anesthesia" [26]. In 2019 based on their experience using VR for patients undergoing Wide Awake Surgery No Tourniquet hand surgery, JHW Clarkson et al published the first example of VR being used for this population [59]. Level II evidence from a randomized prospective controlled single-blind trial demonstrated that patients who used VR reported lower anxiety and experience more fun. In addition, when they studied very anxious patients, these reported lower pain scores during lidocaine injection and that they tolerated WALANT well. Undergoing further evaluation is the role VR has for children specifically, it is the author's observation that they respond very well.

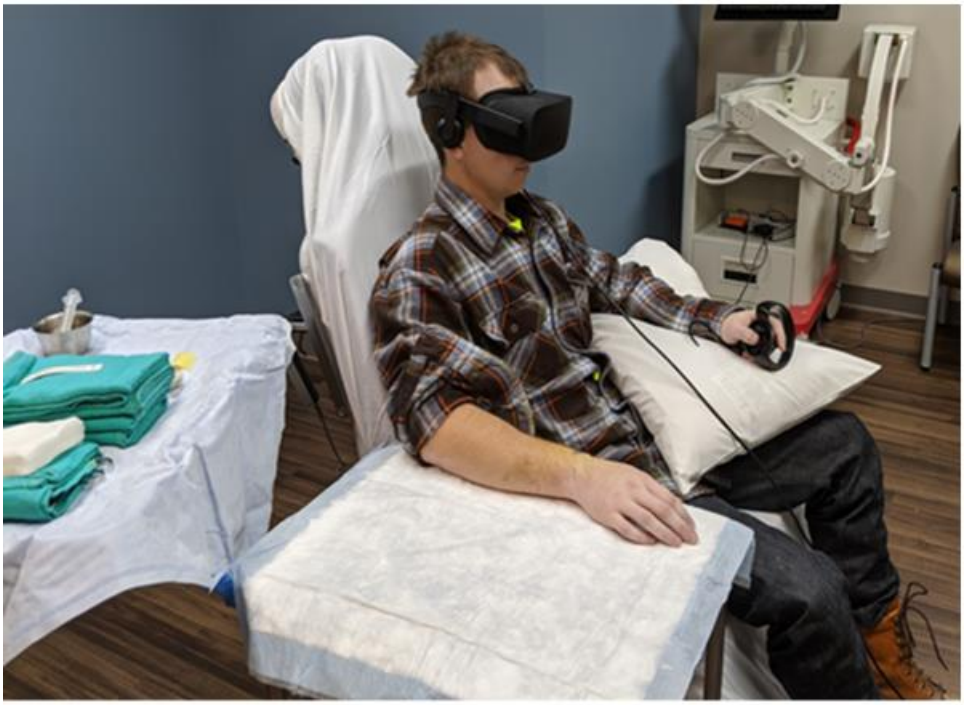


Figure 9. A patient relaxing using Wide Awake Virtual Reality (WAVR) before repair of multiple radial forearm extensor tendon and a superficial radial nerve repair.

Figure 10. A patient preparing for exploration and repair of a zone 6 extensor tendon injury using WAVR.

WAVR empowers the patient to choose WALANT

If the patient lacks the confidence to proceed with WALANT explain that although they will not be put to sleep, they will be taken to another place.

Patient*: "Just put me out doc"*

Doctor: *"How about I put you in another place using virtual reality. It means we can get on immediately to fix your hand. Would you be willing to try this?"*

Encourage the patient to use the VR for a period before surgery begins

In 2020, only a minority of patients have experienced VR. Orientation allows the patient to begin to enjoy themselves and to select the material they want to experience.

Use more than one VR device

Consider using two VR devices, one for the injection room and one for the operating room to improve the flow of the operating schedule. If you only have one device, we find VR most useful during surgery, injections are often better tolerated for the average adult who desires not to experience the surgery.

Very needle-phobic or pediatric patients need VR for injection

Encourage VR for the injection. Give the patient time on the VR before you start the surgery to allow them to understand how to use it and to start to have fun.

Use an easy VR application

We recommend using a suitable app that enables multiple experiences to be chosen from. There are many applications to choose from, we have found the Within™ to be very easy to use. Medical VR applications such as Wide Awake VR™ are in development.

Be sensitive to your choice of VR material

We have only used passive immersive experiences. Interaction such as gaming is also available if one-handed. Music is very effective. Ask the patient if they suffer from motion sickness, if they do, chose sedentary material. Ask the patient for their preferences, their likes and dislikes. Examples we have had include water phobia, a fear of heights and fear of animals. Account for musical taste and choose experiences based on their preferences.

Chose VR material with a long enough duration

It is helpful to have material that has a 20-minute or greater running time, many free experiences last less than 5 minutes requiring frequent reselection.

You may need to control the VR experience

For some patients, you need to control the experience to reduce stress for the patient who may not be familiar with the technology. Other patients will want to take control of the VR device.

Conversation and education are important

Don't forget to talk to the patient, calmly and clearly. You may educate the patient while they watch VR. Monitor the room conversation, they can hear you and everything that is said in the room.

Do not inject without warning

Use the count down from 3 technique and perform skin pinch before inserting the needle

Some patients decline VR

Expect up to 50% of your patients to decline WAVR, this is normal, VR is not for everyone. Beware the very anxious patient who also declines VR; encourage them to try it for some time before deciding. This will relax and condition them for the procedure. Very anxious patients who still decline WAVR may not be suitable for WALANT.

Be aware of patient suitability

Very elderly or poor sighted patients may be more alarmed than assisted by WAVR.

There is a lack of material for VR to be used supine or prone?

In 2020, most VR experiences require the patient to be upright and looking forward; supine and prone experiences are in development by Wide Awake VR™.

Use WAVR to empower patients to choose WALANT
Use more than one VR device
Encourage patients to try VR beforehand
Use VR material greater than 20-minute running time
Select suitable VR material
Avoid needle stick without warning
Expect 40-50% to decline VR
Very elderly or blind may not be suitable
For needle phobic patients use VR during injection of local anesthesia
Speak clearly
Monitor room conversation, they can hear you!

Table 6. Tips on using WAVR in your practice.

As this chapter is being written there is only one commercial system in development designed to implement VR assistant WALANT surgery [60]. Nevertheless, JHW Clarkson was able to demonstrate the utility of generic VR using freely available software on a Galaxy Gear VR device and YouTube 360 videos [59].

Conclusion

As surgeons, we have grown up from the turn of the twentieth century with the availability of general anesthesia. Local anesthesia delivered by injection using painful tourniquets while the patient is conscious and frightened has only enabled our overdependence on sedation and general anesthesia. We must strive to implement new techniques such as WALANT and utilize new technologies such as WAVR to forge a safer more convenient and economic pathway for our patients. It remains to be seen how far hand traumatology evolves towards this model.

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