Regional Anesthesia in Upper-Limb Surgery

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Background: Local and regional anesthesia is associated with numerous clinical and institutional advantages relative to general anesthesia. As anesthesiologists and surgeons increasingly integrate local and regional anesthesia into their clinical practice, an understanding of the principles, evolution, and trends underpinning modern anesthetic techniques continues to be relevant.
Methods: A review of the literature in databases Medline, PubMed, and EMBASE identified recent developments, ongoing trends, and historical milestones in upper-limb regional anesthesia.
Results: Advances in regional anesthetic techniques in the last century have led to reduced postoperative pain, improved safety, and improved outcomes in upper-limb surgery. The development of ultrasound-guided techniques, as well as pharmacological advances in local anesthetic drugs and adjuncts, has further advanced the role of regional anesthesia. Wide-awake local anesthesia with no tourniquet has allowed certain procedures to be performed on select patients in outpatient and low-resource settings.
Conclusions: This review provides an overview of local and regional anesthesia in the upper-limb from its historical origins to its contemporary applications in upper-limb surgery, particularly during the COVID-19 pandemic.

Key Words: anesthesia, local, upper extremity, COVID-19, history of medicine

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Local anesthesia (LA) and regional anesthesia (RA) are associated with numerous clinical and institutional advantages relative to general anesthesia (GA). Upper-limb (UL) RA has evolved significantly from its rudimentary origins. Current RA techniques, including brachial plexus blocks (BPBs) and targeted peripheral nerve blocks (PNBs), as well as Bier blocks and hematoma blocks, can be used to provide surgical anesthesia and postoperative analgesia. Similarly, the wide-awake LA with no tourniquet (WALANT) technique has demonstrable benefits over GA. The advantages of local and RA are particularly applicable in the context of hand surgery, especially in the light of recent health care challenges such as the COVID-19 pandemic and the "opioid-crisis," making local and regional approaches increasingly relevant.

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HISTORICAL BACKGROUND

Local Anesthetic Agents

The introduction of LA began with the isolation of cocaine from the coca plant in 1860.[1] In 1884, Austrian ophthalmologist Dr Karl Koller was the first to use LA in surgery, using topical cocaine for cataract removal.[2] It was subsequently noted that cocaine could be used for cutaneous nerve blockade and dental injection. Procaine (a synthetic formulation of cocaine that did not share its addictive properties) was introduced in the early 20th century.[3] The next major breakthrough was in 1949 with the development of lidocaine (lignocaine), the first non-ester LA.[4] Lidocaine had a host of associated benefits such as a longer duration of action and a reduced incidence of adverse effects. The era of long-acting LAs began with the synthesis of bupivacaine in 1957,[5] and later followed the development of less cardiotoxic agents such as levobupivacaine and ropivacaine.

Equipment and Techniques

Historically, regional nerve blockade was performed based on surface anatomical landmarks. A needle was blindly advanced until paresthesia was elicited and withdrawn slightly before injecting a large volume of LA. This method required an awake patient capable of verbal feedback. The first surgical BPB was performed by William Halsted in 1884.[6] In 1908, August Bier demonstrated his eponymous technique of intravenous (IV) anesthesia in an exsanguinated limb isolated from the body via tourniquet.[7] In 1955, the concept of insulated needles for nerve electro-localization was developed.[8] However, it was not until the late 20th century that the use of peripheral nerve stimulators became widespread. Most recently, ultrasound (US)-guided needle placement has allowed for real-time visualization of anatomy, reducing procedural risk as well as improving block performance. For example, placement of LA closer to the nerve facilitates use of a lower dose (mass) of drug therefore reducing risk of toxicity.

CLINICAL ASPECTS OF UPPER-LIMB REGIONAL ANESTHESIA

Advantages

Regional anesthesia avoids airway manipulation, decreases hypnotic medication requirements, and reduces postoperative nausea and vomiting. It allows for ongoing patient communication throughout the operation and improves patient satisfaction.[9] Avoidance of airway manipulation (an aerosolizing procedure) is desirable in the context of COVID-19.[10] A retrospective review of over 27,000 patients using the North American surgical registry data found that the avoidance of GA in UL procedures reduced the rates of systemic complications including postoperative pneumonia, acute renal failure, and sepsis.[11] Importantly, given the global opioid epidemic, RA has been found to minimize opioid usage postsurgery.[12] Continuous PNBs may also be used to induce sympathectomy and vasodilation to improve blood flow after UL vascular injuries and replantation.[13] However, evidence for use for this indication is limited.

Contradictions

Regional anesthesia is not applicable to all situations and can be associated with complications.

Absolute contraindications include the following:

- Patient refusal
- LA allergy
- Overlying infection. The risk of infection seeding may be modified by selecting an alternate block site.

Relative contraindications include the following:

- Inability to tolerate the PNB awake. This may be managed with the use of sedation before block needle insertion.
- Patient unlikely to tolerate operative procedure awake. Clinicians can consider the use of adjunct sedation or GA.
- Coagulopathy or anticoagulation. Potential iatrogenic bleeding may be reduced by selecting a compressible block site in case of vascular injury.
- Need for immediate postoperative neurological assessment. This problem is circumvented by using short-acting or low concentration LA. Of note, it is generally considered safe to discharge patients (including children) with partial sensory block or continuous PNB infusion with appropriate instruction and follow-up.[14]
- Risk of delayed diagnosis of acute compartment syndrome. Although a commonly cited concern in orthopedic trauma cases, the evidence for RA delaying diagnosis of acute compartment syndrome is poor. Recent multidisciplinary consensus guidelines published by the Association of Anesthetists of Great Britain and Ireland state that single-shot low-dose anesthetic blocks without adjuncts are not associated with delays in diagnosis, provided there is adequate follow-up.[15] Ultimately, use of RA in this context is a joint decision to be made between anesthesiologist, surgeon, and patient after considering the risks and benefits.

Complications

- Failure
- Infection
- Site-specific blockade of unintended structures
- Local anesthetic toxicity
- Vascular injury
- Nerve injury. Mechanisms of peripheral nerve injury (PNI) are often complex and multifactorial, with damage to the perineurium likely to be the most important factor for developing PNB-related neurological injury.[16] The reported risk of severe or permanent PNI is low, approximately 0.01% to 0.04%.[14] Certain techniques and equipment, as well as appropriate patient selection, may decrease this risk.

Blocks performed on awake or sedated patients allows for preoperative assessment of block quality and any immediate complications compared with those who are under GA.[16]

Cost

Studies investigating the cost of RA compared with GA from an institutional perspective report conflicting outcomes. A retrospective cohort study of 1179 patients undergoing elective hand surgery demonstrated a significant reduction in nonsurgical theater time with the use of RA when compared with GA, translating to time and cost savings.[17] In contrast, a retrospective cohort study examining 1587 patients undergoing orthopedic and trauma surgery in Germany identified a cost disadvantage for BPB compared with GA that was inversely proportional to the duration of surgery.[18] The observed differences may be related to the study methodology, which included block performance and onset time in the total case duration. In practice, blocks may be performed in advance during the preceding case. The study also excluded postanesthesia care requirements from cost calculations, which are reduced in RA compared with GA. Ultimately, what is the most cost-effective model in one institution may not be the same for another due to differences in infrastructure and processes that support RA. One such example is the introduction of RA block rooms outside operating theaters, which describes both an actual location as well as a system of parallel processing that has been shown to improve theater efficiency in total joint arthroplasty.[19]

EQUIPMENT

Advances in equipment that have improved the safety and efficacy of RA include the following.

Needle Type

Short beveled blunt (45 degrees) needles are less likely to pierce the perineurium of peripheral nerves compared with long beveled sharp needles (12 to 15 degrees). The use of short-bevel needles theoretically reduces the risk of PNI during PNBs[20] and has become standard practice.

Echogenic needles, such as the Stimuplex (B. Braun, Melsungen, Germany) or the SonoPlex (Pajunk, Geisingen, Germany), have been specifically designed with a textured surface to improve visibility under US.

Ultrasound

Ultrasound-guided PNB is considered standard of care due to improved efficacy and safety compared with landmark or nerve stimulation-based techniques. A meta-analysis of 16 randomized controlled trials investigating brachial plexus blockade revealed greater success and decreased rates of complications with US guidance when compared with nerve stimulation blocks.[21]

Ultrasound diminishes the risk of systemic LA toxicity via a reduction in dose requirements and rates of accidental intravascular injection.[22] However, the reduction of other postoperative neurological complications has not been conclusively demonstrated.[23] This may be attributable to the low overall incidence of perioperative PNI in UL RA.[24] As PNI is multifactorial, other influences including patient body habitus, surgical factors, and direct chemical injury from LA or adjuvants may mask the beneficial effects of US guidance.

Nerve Stimulators

Peripheral nerve stimulators aim to identify nerves by eliciting muscular contractions. Appropriate motor response at 0.5 mA or less is considered a needle-to-nerve position that is sufficient for accurate and safe injection of LA. However, this motor response has been shown to be unreliable, even with US confirmation of the needle tip indenting the neural surface.[25] Persistent twitching at currents of less than 0.2 mA may indicate accidental intraneural needle placement, and local anesthetic should not be deposited in this location. In addition, nerve stimulation combined with US does not appear to improve block success rates.[26] For these reasons, electro-localization methods have fallen out of favor in modern practice.

Continuous Catheter Peripheral Nerve Block

Local anesthetic may be delivered by electronic or elastomeric pumps through a catheter to provide continuous PNB. The role of continuous catheter PNB is well established in shoulder and upper arm surgery, particularly the infraclavicular and interscalene blocks.[27] Evidence supporting their use in hand surgery is less robust. Case series have demonstrated advantages in pain control using continuous PNBs for severe hand trauma[28] and early active mobilization following tenolysis and arthrolysis.[29] A disadvantage of their use is the requirement for postinsertion care and follow-up.

PHARMACOLOGICAL AGENTS

Local Anesthetics

Local anesthetics are divided into 2 main groups based on chemical structure—esters and amides. Ester compounds (such as prilocaine or tetracaine) are more rapidly hydrolyzed and metabolized by plasma pseudocholinesterases, with significantly shorter half-lives than amides. Ester compounds are more prone to hypersensitivity reaction. Thus prilocaine remains the only ester LA still commonly used in RA, where it is used in Bier blocks due to its rapid metabolism (Table 1, Table 2).

Amide compounds are identifiable by having 2 "I's" in their name. Lidocaine is used when a quicker onset of action and shorter duration of block is desirable. Speed of onset is influenced by drug acid strength (pKa), which is lower (and therefore closer to physiological pH) in lidocaine at 7.9, compared with 8.1 for both ropivacaine and bupivacaine. Duration of action is influenced by lipid solubility and tissue protein binding, which are both significantly higher in ropivacaine and bupivacaine compared with lidocaine. Ropivacaine is considered to have less risk of cardiac toxicity and may cause less motor blockade than bupivacaine at equipotent doses.[30] Ropivacaine has inherent vasoconstrictive properties and does not come premixed with adrenaline. However, manual addition of adrenaline to ropivacaine by surgeons for local infiltration may occur.

The choice of local anesthetic and concentration used in PNBs will depend on the goals of RA such as onset, duration, and depth of block. All types of amide LAs can be used for all types of blocks. Higher concentration LAs have a faster onset and longer duration of block; however, they theoretically have a higher risk of neurotoxicity. For example, lidocaine 1% + ropivacaine 0.5% might be used in a standalone RA technique to provide complete anesthesia, whereas ropivacaine 0.2% might be considered where RA is used to supplement GA for analgesic purposes.

Pharmacological Adjuncts to Local Anesthetics

Several agents can be combined with local anesthetics to increase tolerability, prolong duration of analgesia, and improve safety. These include the following:

• Sodium bicarbonate

Sodium bicarbonate can be used to increase the pH of the LA solution, which can reduce pain on injection and hasten onset. However, care must be taken not alkalinize the solution excessively, as this can result in precipitation of the LA.

• α-2-Agonists such as clonidine and dexmedetomidine

α-2-Agonists injected near peripheral nerves cause activation of G protein–coupled receptor associated with the Gi (inhibitory) subunit. Therefore, drugs such as clonidine and dexmedetomidine work to hyperpolarize neurons to prevent ascending sensory signal transmission. Clonidine added LAs for single-shot PNBs or BPBs prolongs duration of analgesia and motor block by approximately 2 hours.[31] Dexmedetomidine (with greater selectivity for α2 receptors) has shown similar benefits.[32]

TABLE 1. Commonly Used Local Anesthetics in Upper-Limb Surgery

Drug Name	Class	Maximum Dose
Lignocaine	Amide LA	3 mg/kg (plain) 7 mg/kg (with adrenaline)
Bupivacaine	Amide LA	2 mg/kg
Ropivacaine	Amide LA	3 mg/kg

TABLE 2. Commonly Used Local Anesthetic Adjuncts in Upper-Limb Surgery

Drug Name	Class	Typical Peripheral Dose
Clonidine	α-2-agonist	0.5 μg/kg
Dexmedetomidine	α-2-agonist	1 μg/kg
Dexamethasone	Corticosteroid	4–8 mg
Adrenaline	Naturally occurring catecholamine	Up to 3 μg/kg

• Dexamethasone

Dexamethasone is a glucocorticoid with a minimal adverse side effect profile. When given either intravenously at the time of blockade, or mixed in with local anesthetic and injected perineurally, it has been shown to significantly prolong duration of LA. A randomized control trial of dexamethasone injected perineurally in patients undergoing elective UL surgery demonstrated prolonged supraclavicular BPB analgesia by approximately 10 hours.[33] A Cochrane review of 35 randomized control trials, which incorporated multiple different types of PNB, showed dexamethasone prolonged sensory block by approximately 6 hours.[34] However, dexamethasone may also undesirably prolong the duration of motor blockade, and therefore its use should be considered on a case-by-case basis.

• Adrenaline

The addition of dilute adrenaline decreases systemic uptake via vasoconstriction and therefore permits greater volumes of local anesthetic to be used. Although traditional teaching recommends that LA containing adrenaline should be avoided in fingers and other extremities such as toes or the penis, this idea has been refuted in many basic and clinical studies and is considered safe.[35]

TECHNIQUES OF REGIONAL ANESTHESIA OF THE UPPER LIMB

The UL can be anesthetized in various locations, depending on the requirements for surgery.

Brachial Plexus Blocks

There are 4 primary approaches to blocking the brachial plexus—interscalene, supraclavicular, infraclavicular, and axillary. The location for each of these approaches, as well as the expected sensory distribution of the resultant anesthesia, is summarized below in Figure 1.

Intercostobrachial Nerve

The intercostobrachial nerve may require supplementary blockade, as it is not anesthetized with most BPBs. It supplies sensation to the medial upper arm, and its blockade may be useful for reducing pain associated with upper arm tourniquet compression (see Fig. 2). Its relatively constant course ensures that it can be anesthetized consistently by depositing a wheal of local anesthetic superiorly and inferiorly along the axillary crease without the need for US guidance.

Peripheral Nerve Blocks at the Elbow, Distal Forearm, and Wrist

Blockade of peripheral nerves may be used as a standalone technique for hand or wrist surgery, or as a means of supplementing an

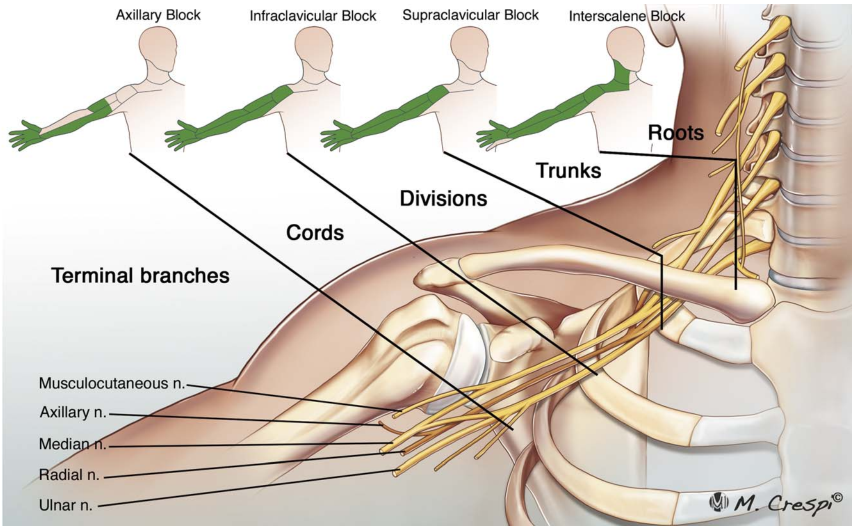

FIGURE 1. BPBs and their expected sensory distributions. Note: the infraclavicular block often includes the intercostobrachial nerve, and the axillary block can include the musculocutaneous nerve, which is not demonstrated on this diagram.

incomplete BPB. Peripheral nerve blocks can provide more selective anesthesia or analgesia with less associated motor blockade. One small, randomized study demonstrated similar efficacy in experienced anesthesiologists using US-guided forearm blocks compared with BPBs in patients undergoing hand surgery under sedation.[36] The use of selective regional wrist blockade has been shown to decrease the pain of tumescent infiltration in WALANT finger and hand surgery and increase patient satisfaction with surgery.[37]

Radial Nerve

Blockade of the radial nerve is indicated for isolated surgery to the dorsoradial aspect of the hand. The landmark technique for blockade is achieved approximately 1.5 cm lateral to the biceps tendon at the elbow crease. With US guidance, the nerve is visibly deep to the brachioradialis muscle. The radial nerve may be difficult to follow distally from the elbow, and it is usually the superficial branch that is visualized for blockade.

Ulnar Nerve

The ulnar is commonly blocked at the elbow, in the ulnar groove in between the medial humeral epicondyle and the olecranon. If a block is performed at this location, it is recommended to avoid injection of excessive volumes of fluid to minimize the risk of increased pressure on the ulnar nerve in a relatively tight space.

Median Nerve

Although the anatomical landmark technique is often performed just medial to the brachial artery at the elbow crease, US guidance can be used at the mid forearm. This location is preferred as it allows avoidance of the brachial artery, as well as adequate differentiation of nerves from tendons, which can have a similar sonographic appearance.[38]

Lateral and Medial Cutaneous Nerves of the Forearm

The lateral and medial cutaneous nerves of the forearm may be blocked for superficial procedures of the anterior forearm. These blocks are commonly performed using an anatomical landmark technique, deep and lateral to the biceps tendon along the intercondylar line. Because of the considerable overlap in distribution between the cutaneous nerves of the forearm, they are usually blocked simultaneously.

Digital Block

There are 3 main approaches to performing digital nerve blockade: transthecal (flexor tendon sheath block), transmetacarpal, and subcutaneous. A randomized, single-blinded study on 50 healthy volunteers comparing the 3 methods found no significant difference in pain level between the methods.[39]

Bier Block

A Bier block is an eponymous name for the injection of LA via an IV catheter into an exsanguinated limb that has been isolated from the central circulation by tourniquet. This block may be used for brief procedures of the upper or lower limb, such as closed reduction of

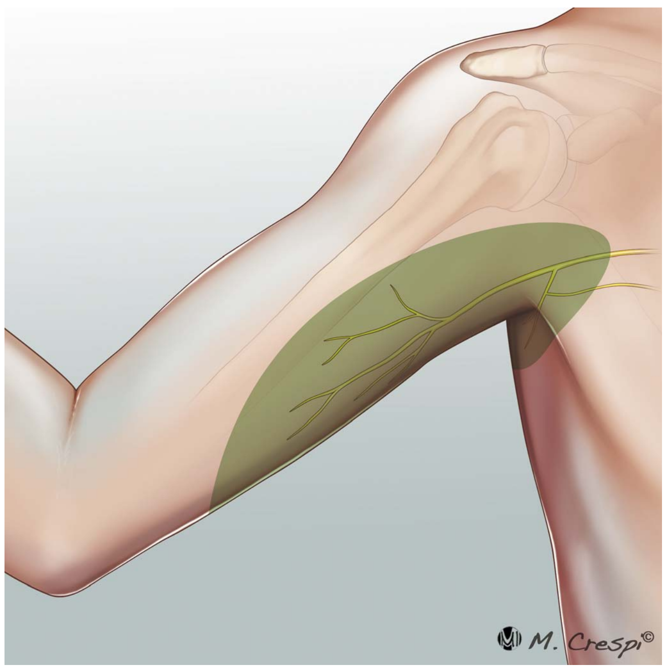

FIGURE 2. Sensory distribution of intercostobrachial nerve block.

fractures. Careful tourniquet inflation and deflation must be performed to avoid systemic toxicity. In experienced hands, it is considered a safe and effective technique.[40]

Hematoma Block

A hematoma block is a simple method of providing LA around the site of a fracture when reduction or manipulation is required. It is contraindicated in open fractures. The use of hematoma blocks can be used as an alternative to procedural sedation for the closed reduction of distal radius fractures in the pediatric[41] and adult populations.[42]

LOCAL INFILTRATION AND WALANT

In contrast to peripheral nerve or BPBs, WALANT does not block specific nerves but involves infiltration of large amounts of dilute LA containing adrenaline. When injected up to 2 cm beyond the site of incision, a suitable surgical field can be established (Table 3).[51] For a 70-kg patient, just under 50 mL of 1% lidocaine with 1:100,000 adrenaline can safely be injected, which will provide suitable analgesia within minutes and maximal vasoconstriction after 30 minutes. If larger volumes are required, this solution can be diluted to either half (lidocaine 0.5% with 1:200,000 adrenaline) or even quarter strength (lidocaine 0.25% with 1:400,000 adrenaline) to provide adequate LA and hemostasis for up to 3 hours. Bupivacaine and ropivacaine are not considered suitable local anesthetic agents in WALANT due to their prolonged duration of effect in day surgery settings and much higher potential for cardiac toxicity.

Small technical details such as the use of finer needles, for example, 30 gauge, buffering with sodium bicarbonate and injection from proximal to distal have been described as methods to reduce pain of injection.[52] Similarly, the use of blunt tipped flexible metal cannulas for tumescing large areas can further decrease pain of injection.[53] WALANT has been used for routine procedures such as carpal tunnel release, trigger finger release, and nerve repair. Unlike standard

TABLE 3. Comparison of the BPBs Available

BPB	Target	Distribution	Advantages	Disadvantages	Comparison to Other BPBs
Interscalene	C5, C6, and C7 nerve roots	Shoulder and upper arm	Effective anesthesia for procedures of the shoulder joint, lateral two thirds of the clavicle, and proximal humerus Consistently blocks the supraclavicular nerve (C3–4)[43]	Almost 100% ipsilateral diaphragmatic paralysis due to the proximity of the phrenic nerve[44] (hence cautious use in patients with underlying respiratory disease) Ipsilateral Horner syndrome due to the proximity of the cervical sympathetic ganglion Recurrent laryngeal nerve blockade with vocal cord palsy	Unreliable coverage of C8/T1 nerve roots, therefore inappropriate for hand surgery
Supraclavicular	Upper, middle, and lower trunks at the infraclavicular fossa	Shoulder and distal two thirds of upper extremity	Superficial view of brachial plexus (easy to visualize) Shallow needle angle facilitates needle visualization Much lower risk of phrenic nerve blockade compared with interscalene, especially with US guidance[45] Relatively fast onset[14] High success rate (greater than 90%)[25]	Unlikely to cover intercostobrachial nerve (poor tourniquet coverage) Risk of pneumothorax Difficult to compress site in case of arterial puncture	Increased ulnar sparing (lower trunk deep and medial to needle insertion point)
Infraclavicular	Medial, posterior, and lateral cords at the infraclavicular fossa	Distal two thirds of the upper extremity	Likely to cover intercostobrachial nerve (good tourniquet coverage)[46] Low risk of pneumothorax[47] High success rate (approximately 90%)[47]	Brachial plexus deep at this point (harder to visualize with US, and steep needle angle impedes needle localization) Difficult to compress site in case of arterial puncture Relatively slow onset[46]	
Axillary	Radial, ulnar, median, and musculocutaneous nerves in the axilla	Elbow, forearm, and hand (does not appropriately cover shoulder or arm)	Superficial (easy to visualize with US, shallow needle angle facilitates needle localization) Minimal phrenic nerve blockade and pneumothorax risk[48] Superficial (easy to visualize with US, shallow needle angle facilitates needle localization) Compressible in case of arterial puncture	Longer performance time[49] Unlikely to cover intercostobrachial nerve (can be supplemented with intercostobrachial nerve block)	Similar incidence of tourniquet pain to infraclavicular[50]

regional anesthetic techniques, WALANT can be performed in an office-based setting with a reduced number of resources and without an anesthesiologist, increasing the accessibility and affordability of hand surgery in select circumstances.[52] The use of WALANT for trigger finger releases has demonstrated a cost benefit over a standard tourniquet, operating room approach.[54] WALANT can be performed by surgeons (or anesthesiologists) on patients in between surgical cases to minimize theater turnover time and improve efficiency.

FUTURE DIRECTIONS OF UPPER-LIMB REGIONAL AND LOCAL ANESTHESIA

Regional techniques will remain an important aspect of multimodal anesthesia for UL surgery in the future. This has particularly been highlighted during the COVID-19 pandemic, with the United Kingdom Royal College of Anesthetists advocating for the use of RA over GA where possible to reduce aerosol generating procedures, diminishing the use of personal protective equipment and preserve patient immune function.[10] This push has resulted in institutions developing and expanding the use of routine WALANT protocols for hand surgery.[55] Furthermore, the use of RA to reduce postoperative analgesia use is important in the context of the global opioid crisis. To promote the increased use of RA, there must be an accompanying change in cultural acceptance, education, and patient expectations.

Technological advances speculated to improve needle guidance may include increasingly echogenic needles, improved US software, and 3-dimensional imaging.[56] Better image resolution of anatomical structures that have the potential to visualize previously unidentifiable structures could lead to novel PNBs. The reduced cost and miniaturization of US machines compared with when they were first introduced in the 1990s has expanded the scope of RA. For example, portable battery-operated US machines have been used in the prehospital setting to assist reduction of dislocated upper extremity injuries.[57]

Further development and research of pharmacological agents, such as sustained-release LA, may alter the landscape of RA in UL surgery. An example is liposomal bupivacaine, which can provide effective analgesia for up to 48 to 72 hours.[58] Currently, the use of liposomal bupivacaine is not widespread due to cost and limitations in approval. Local infiltration of liposomal bupivacaine was shown to reduce opioid consumption in the 5 days after thumb carpometacarpal arthroplasty compared with no local anesthetic infiltration.[59] A recent meta-analysis demonstrated that peripheral nerve blockade with liposomal bupivacaine demonstrated a statistically significant but clinically unimportant improvement in postoperative pain scores compared with standard bupivacaine.[60] Further high-quality evidence will be required for widespread uptake of this drug in UL surgery.

There is ongoing research into anatomical block techniques to improve the safety and efficacy of UL RA. Techniques that minimize needle passes increase speed and reduce infection risk.[61] One area of interest is fascial plane blocks—injection of local anesthetic into fascial planes rather than around discrete nerves—which has been commonly used in thoracic and abdominal regional analgesia. Ergonomic technologies such as head-mounted displays may become more common in the future, providing continuous real-time US imaging within the operator's visual field to improve block performance.[62]

Lastly increased training, standardization, and governance will lead to improved clinician access and confidence in the available techniques. For example, the American Society of Regional Anesthesia and Pain Medicine is considering standardization of RA training for anesthesiologists. The use of high-fidelity simulators and the development of consensus guidelines of high value basic US-guided RA techniques are ways in which this issue can be addressed. Safety protocols, checklists, and procedural timeouts have been increasingly used over the last decade. Their use is now considered criterion standard in reducing rare but serious adverse outcomes.[63]

SUMMARY

Developments in UL RA and LA have allowed for better patient and institutional outcomes than previously possible. Improvement in the efficacy and safety of RA has seen a gradual evolution from blind-landmark injection techniques of the first half of the 20th century to the targeted application of contemporary US-guided injections. Regional anesthesia and LA should be seen not only as an alternative to GA, but as part of a wider multimodal analgesic strategy, which involves input from the patient, surgeon, and anesthesiologist. Risks posed by operating during the COVID-19 pandemic have driven an increase in the use of RA and LA in UL surgery. Innovation in equipment and techniques is expected to improve the utility of RA and LA in UL surgery in the future.

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