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Comparing Efficacy and Safety Aspects of 2% Lidocaine Hydrochloride Combination with 1:80.000 Added Epinephrine Solution versus the Most Commonly Used 2% Lidocaine Hydrochloride Solution in Surgical Procedures on Human Fingers and Toes

Ahmad Fawzy

Department of Plastic Surgery, Faculty of Medicine University of Jenderal Soedirman - Margono Soekarjo Hospital, Indonesia

ABSTRACT

The effective management of pain and hemostasis is a pivotal concern in surgical procedures performed on human fingers and toes. The anatomical intricacies and limited tissue volume demand a meticulous approach to ensure both the safety of the patient and the successful outcome of the surgery. The use of vasoconstrictor agents, such as epinephrine, to provide clear surgical field and better surgical outcome further complicates the landscape. While epinephrine is a valuable adjunct to local anesthesia due to its hemostatic properties and ability to prolong anesthetic effects, its application in procedures on fingers and toes necessitates a deep understanding of potential risks and complications. This literature review delves into the comparative analysis of two widely employed local anesthetic solutions which are the 2% lidocaine hydrochloride solution and the 2% lidocaine hydrochloride solution combined with 1:80,000 epinephrine, with specific aim to comprehensively evaluate the efficacy and safety aspects of both local anesthetic solutions. Lidocaine solution alone offers effective pain relief with minimal systemic risks but might lack the extended duration and hemostasis benefits of epinephrine. The lidocaine-epinephrine combination solution provides prolonged anesthesia and reduced bleeding, but clinicians must balance these advantages with the potential for ischemic events and delayed wound healing. Close monitoring, precise dosing, and careful patient selection are paramount in ensuring successful outcomes while minimizing complications.

KEYWORDS: lidocaine, epinephrine, vasoconstriction, ischemic tissue, surgical safety

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INTRODUCTION

The effective management of pain and hemostasis is a pivotal concern in surgical procedures involving the intricate anatomy of human fingers and toes. Local anesthesia forms the cornerstone of achieving these goals while ensuring patient comfort and favorable outcomes. This literature review delves into the comparative analysis of two widely employed local anesthetic solutions: 2% lidocaine hydrochloride solution and 2% lidocaine hydrochloride solution combined with 1:80,000 epinephrine. Specifically, it aims to comprehensively evaluate the efficacy and safety aspects of these two formulations in the context of surgical interventions on human fingers and toes.

Lidocaine, the most commonly used local anesthetic, has established itself as a reliable agent in providing rapid and short-to-intermediate duration anesthesia.[1] On the other hand, the combination of lidocaine with epinephrine introduces an intriguing dimension to local anesthesia, capitalizing on vasoconstrictive properties of epinephrine to extend anesthesia duration and curtail bleeding.[2,3] The comparative analysis of these formulations in the context of digital surgical procedures warrants careful consideration due to the unique vascular and anatomical characteristics of fingers and toes. The balance between effective pain relief, hemostasis, and the potential for ischemic events demands meticulous evaluation. As such, this review endeavors to contribute to a nuanced understanding of the advantages and potential drawbacks associated with these two prominent local anesthetic solutions, offering insights that can guide clinical decision-making and optimize patient outcomes in surgical interventions involving the delicate structures of human fingers and toes.

Surgical procedures on human fingers and toes

Surgical procedures involving human fingers and toes present a unique set of challenges and considerations in the field of surgery. The anatomical intricacies and limited tissue volume demand a meticulous approach to ensure both the safety of the patient and the success of the surgical outcome. The use of vasoconstrictor agents, such as epinephrine, further complicates the landscape. While epinephrine is a valuable adjunct to local anesthesia due to its hemostatic properties and ability to prolong anesthetic effects, its application in procedures on fingers and toes necessitates a deep understanding of potential risks and complications.[4]

The anatomical site of local anesthetic injection in human fingers and toes is a critical consideration to ensure optimal pain relief and surgical precision. Injection sites are strategically chosen to target the neurovascular bundles supplying these digits. In the fingers, injections are commonly administered at the base of the digit, either volarly or dorsally, to access the digital nerve and its associated vessels. The choice between these sites depends on the specific surgical procedure and the need for sensory blockade. Careful attention to the anatomy of the neurovascular bundles is crucial to avoid damage to vital structures and to achieve effective anesthesia. In the toes, injections are similarly directed towards the base of the digit, aiming to anesthetize the digital nerve and its vascular supply. Similar to the fingers, the appropriate injection site is determined by the specific surgical intervention and the desired extent of anesthesia. Understanding the precise course of the digital nerves and vessels is essential to avoid inadvertent trauma or vascular compromise during injection. Adequate knowledge of the anatomical relationships between these neurovascular structures aids in achieving successful local anesthesia, mitigating patient discomfort, and enhancing ability of the surgeon to execute intricate procedures with finesse.

Safety remains paramount in surgeries on fingers and toes due to their distal location and susceptibility to compromised circulation. Vasoconstrictive effect of epinephrine is advantageous in minimizing bleeding, enhancing visibility, and prolonging anesthesia. However, this effect can potentially tip the delicate balance of blood supply in these digits, leading to ischemia or even digital necrosis if not judiciously administered. The challenge lies in precise dosing and meticulous application to avoid prolonged vasoconstriction that could compromise tissue viability.

Risk assessment and anticipation of complications are essential in procedures involving vasoconstrictors like epinephrine. Complications can range from transient blanching and pallor to more severe ischemic events. Careful patient selection, thorough pre-operative evaluation, and consideration of medical history are crucial to identify those at higher risk of adverse effects. Additionally, vigilant intraoperative monitoring is essential to promptly identify signs of compromised circulation, enabling timely intervention. The potential for delayed wound healing due to reduced perfusion must also be taken into account, particularly in procedures requiring meticulous tissue approximation.

Lidocaine hydrochloride

A solution of 2% lidocaine hydrochloride stands as a stalwart in the realm of local anesthesia, a cornerstone in surgical and medical practices requiring effective pain management. This local anesthetic agent demonstrates a rapid onset of action, rendering it suitable for a wide array of procedures that necessitate prompt and targeted pain relief. The anesthetic potency of lidocaine is attributed to its capacity to selectively inhibit voltage-gated sodium channels, thereby leading to the suppression of nerve impulse propagation and subsequent sensory and motor blockade.[1-3]

Lidocaine is classified as an amide-type local anesthetic, a class renowned for its potency and versatility. Upon administration, lidocaine penetrates neuronal membranes, with a preference for binding to the inactivated state of voltage-gated sodium channels. This binding prevents the channels from transitioning to their active state, effectively diminishing the influx of sodium ions required for action potential propagation along nerve fibers (see **Image 1**).[5-8]

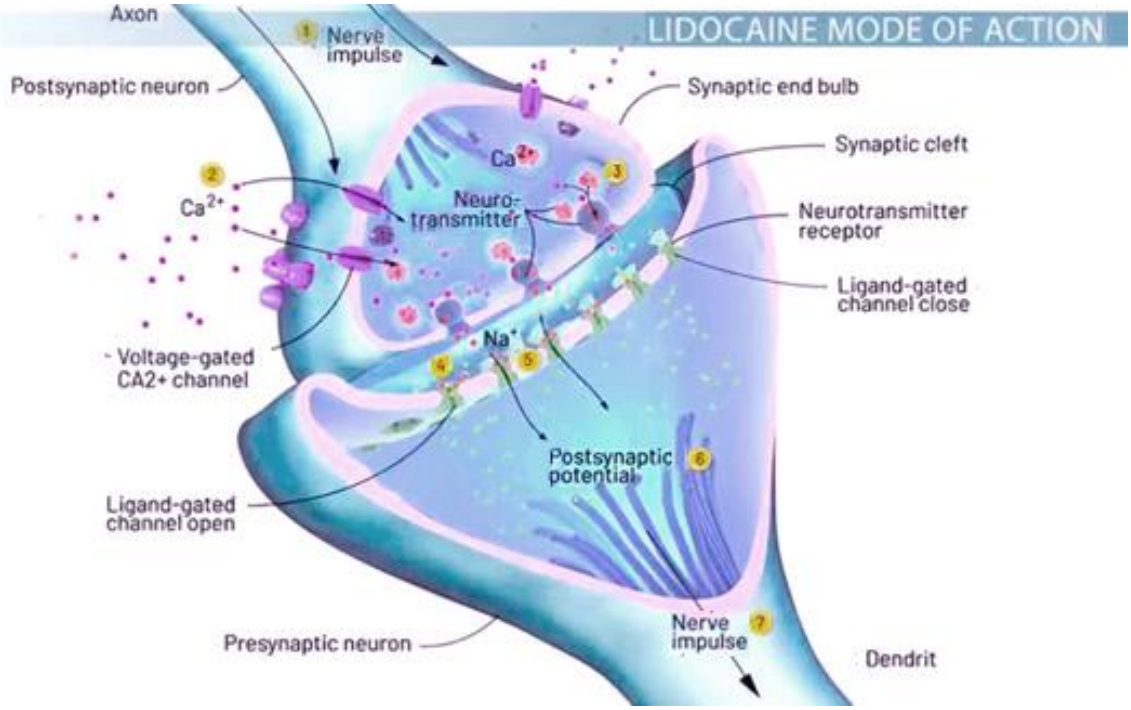

Image 1. Lidocaine mode of action

The significant mechanism of action of lidocaine extends beyond its anesthetic properties. Its preferential binding to inactivated sodium channels distinguishes its selectivity for actively firing neurons, which are often associated with pain transmission. The cascade of events following its interaction with sodium channels culminates in a series of effects that render the nerve fibers incapable of transmitting signals. This includes preventing depolarization, impeding the conduction of nerve impulses, and subsequently inducing sensory and motor blockade. This property contributes to its safety profile, as it tends to exert its effects more profoundly in tissues undergoing high-frequency firing, such as those in inflamed or sensitized areas. Additionally, the reversible nature of its interaction with sodium channels enables a predictable and controlled recovery of nerve function, further underpinning its reliability as a local anesthetic agent.[9] In sum, the mechanism of action of 2% lidocaine hydrochloride aligns with its role as a key tool in plastic surgical practices, ensuring pain relief without compromising the essential functions of nerve fibers.

The versatility of 2% lidocaine hydrochloride extends to its compatibility with various routes of administration, including topical application, infiltration, nerve blocks, and intravenous regional anesthesia (Bier block).[1] This flexibility underscores its utility in an array of surgical interventions, from minor dermatological procedures to more complex reconstructions. However, it is prudent to note that despite its efficacy, its duration of action is of intermediate length.[1,10] necessitating additional doses or combinations with agents like epinephrine for prolonged surgical procedures or those requiring post-operative pain management.

While 2% lidocaine hydrochloride remains a stalwart in local anesthesia, certain considerations warrant attention. The risk of systemic toxicity, though low when used judiciously, underscores the importance of accurate dosing and careful monitoring, especially in distal anatomical areas like fingers and toes. Furthermore, in procedures demanding extensive infiltration or in patients with certain medical conditions, the total dose of lidocaine must be scrutinized to prevent potential adverse effects. Ultimately, the robust track record of 2% lidocaine hydrochloride, when wielded skillfully and within safe parameters, accentuates its value in enhancing patient comfort and optimizing surgical outcomes across the spectrum of plastic surgical endeavors.

Safety and efficacy of 2% lidocaine hydrochloride

The anesthetic efficacy of 2% lidocaine hydrochloride stands as a testament to its integral role in modern surgical practices. One of the hallmark attributes contributing to its widespread use is its rapid onset of action.[11] Following administration, lidocaine rapidly diffuses across neuronal membranes, reaching its target sodium channels within nerve fibers. This swift penetration allows for a prompt establishment of sensory and motor blockade, culminating in the attenuation of nerve signal transmission and subsequent pain perception.[1,5-9] The ability of 2% lidocaine to promptly render the treatment area insensitive to painful stimuli facilitates the smooth execution of various surgical procedures, enhancing patient comfort and surgical precision alike.

A solution of 2% lidocaine hydrochloride, when used within recommended doses, carries a low risk of systemic toxicity. The maximal dose and lethal dose are pivotal considerations

in ensuring patient safety during surgery procedures. Surgeons apply the recommended dose based on the body weight of the patient, usually give a dose of 4 mg per kilogram of body weight, with precaution not to exceed 7 mg per kilogram of body weight. However, it is imperative to note that higher doses might be employed in specific cases under strict supervision. Lethal doses of lidocaine have been reported in the literature, however there is no universally fixed value as it can vary greatly among individuals due to factors such as age, overall health, and individual sensitivity. Clinicians agree that exceeding the recommended maximal dose of 300 mg significantly increases the risk of life-threatening systemic toxicity. It's crucial for surgeons to adhere to safe dosing guidelines, carefully monitor patients, and consider individual factors, especially as we acknowledge that the limited surface area and potential for faster absorption in fingertips/toes.[1,12]

The intermediate duration of action of 2% lidocaine hydrochloride is a crucial feature that aligns with the dynamic demands of surgical interventions. As an amide-type local anesthetic, lidocaine interacts with sodium channels in a reversible manner. This attribute endows it with the capacity to provide a sustained period of anesthesia without undue persistence. The intermediate duration strikes a balance between swift recovery of nerve function post-operatively and the need for effective pain relief throughout the course of a procedure. This is particularly advantageous for minor to moderate surgical interventions, allowing for a predictable return of sensation while concurrently minimizing the need for frequent re-administration.[1,5-10] However, its duration of action may be modulated by the added presence of vasoconstrictors like epinephrine, which can prolong anesthesia by restricting the systemic absorption of lidocaine.[2,3] In the realm of plastic surgery, where precise pain management and optimal procedural conditions are of utmost importance, the interplay between kinetic attributes of lidocaine and the specific demands of the surgical context elevates its significance as a versatile anesthetic agent. Studies stated that the use of lidocaine in surgical procedures on fingers and toes generally showing good viability post-operatively.[13] However, all surgeons should consider and anticipate the potential for compromised circulation if applying a combination of lidocaine and vasoconstrictor in these distal areas.

Lidocaine with epinephrine combination

The addition of epinephrine in a concentration of 1:80,000 to lidocaine serves as a valuable augmentation strategy in local anesthesia. Vasoconstrictive properties of epinephrine significantly extend the duration of anesthesia by constricting blood vessels at the injection site, which in turn delays the systemic absorption of lidocaine. This not only prolongs the pain-relieving effects but also curtails systemic distribution, reducing the risk of potential systemic toxicity associated with higher doses of lidocaine.[2,3] This effect becomes particularly advantageous in complex or lengthy finger or toe surgical procedures, where maintaining a consistent level of anesthesia is pivotal for surgeon precision and patient comfort.

Controlling intraprocedural bleeding in finger and toe surgeries is important to maintain a clear surgical field and optimize outcomes. In the past, medical students learned that using vasoconstrictor injection like epinephrine in combination with local anesthetic agents should never be into considerations for distal anatomical structures like fingers, toes, noses or ears due to its potential risk of distal ischaemia and necrosis,[14] hence all surgical procedures on the distal structures of upper and lower extremities use external pressure techniques, such as tourniquets, to effectively minimize blood flow during procedures and consequently enhancing visibility and precision of surgical maneuvers. However, such application must be judicious, considering there is still the risk of potential ischemic events in the distal anatomical regions should the tourniquet be applied in a long duration.

Another alternative pressure technique is tumescent technique proposed by Prasetyono which involves injecting a dilute solution of one-per-mil epinephrine (1:1,000,000) as a substitute for tourniquet application.[15] The tumescent technique using epinephrine eliminates the doubts of controversy surrounding the use of vasoconstrictors and its risk of compromised circulation. In recent years, applications of lidocaine-adrenaline combination have generally maintained viability in fingertips/toes. By enhancing the duration of anesthesia and minimizing bleeding, the combination of lidocaine hydrochloride and epinephrine contributes to creating a controlled surgical environment, optimizing outcomes in procedures that demand a high degree of accuracy and where maintaining the clear surgical field is paramount. Surgeons mitigate the concerns and risks of potential ischemic events by performing careful administration and meticulous monitoring so they can achieve the overall safety and success of finger and toe surgical procedures..As long as the surgeons keep lidocaine with epinephrine combination in doses below the maximum dose recommended by Food and Drug Administration, they can anticipate no serious adverse events requiring emergency intervention.[16]

Risks and anticipated complications of lidocaine with epinephrine combination

During surgical procedures for fingers and toes, prolonged vasoconstriction from epinephrine may elevate the risk of ischemic events, such as digital necrosis. Careful patient selection, proper dosing, and intraoperative vigilance can mitigate this risk. The vasoconstrictive properties of

epinephrine might extend beyond the surgical site, affecting circulation in surrounding tissues. Awareness of this potential complication is crucial.

There is also a slight risk of vasoconstrictive effects of epinephrine impeding wound healing in fingertips or toes. However, this risk is often outweighed by the benefits of reduced bleeding during surgery.

Evidence-based studies

In 2001, one retrospective review study of 1,111 digit or hand surgery cases in which 611 patients received lidocaine with epinephrine, none in the epinephrine group experienced digit necrosis,[14] Another retrospective review identified 63 patients who had digit surgery with lidocaine with epinephrine and found no cases of digital ischemia or necrosis.[17] In 2014, one systematic review based on six English literatures from Medline, Cochrane Central Register of Controlled Trials, The Allied and Complementary Medicine Database (AMED), and the Cumulative Index to Nursing and Allied Health Literature (CINAHL) databases concluded that lidocaine with epinephrine provides a good short-term anesthesia and may reduce the risk of injury or complication while the finger in still anesthetized.[18]

Although the current available randomized controlled trial evidence suggests that the addition of epinephrine to lidocaine in digital nerve anesthesia prolongs anesthesia duration and reduces bleeding during surgery, with low risk of digital ischemia, there is still not enough high-quality evidence to recommend or refute the routine use of lidocaine with epinephrine for digital nerve anesthesia. Further prospective randomized controlled trials of high methodological quality with patient-centered outcomes are needed to establish the benefits, risks, and best practice recommendations.

Author's experience

Since 2010, author has been using the combined preparation of 2% lidocaine hydrochloride with 1:80.000 added epinephrine solution to substitute the use of tourniquet for elective reconstructive procedures on fingers and toes, which consist of 746 finger contractures, 57 polydactylies, 21 syndactylies and fused toes. All procedures showed favorable results without compromised finger/toe or digital tip necrosis. All adult patients receiving surgical procedures with duration of less than an hour admitted they still felt comfortable sensory feeling in the first hour after the injection. This is in accordance with one study that reported the mean pain intensity in the first postoperative hour was numerically lower after lidocaine 2% with epinephrine 1:80,000 compared to the pain intensity after lidocaine 2%, while the mean pain intensity after lidocaine 2% was lower than that after lidocaine 2% with epinephrine 1:80,000 throughout the remaining observation period.[19]

CONCLUSION

In surgical procedures on human fingers and toes, the choice between lidocaine and lidocaine-adrenaline combination depends on various factors. Lidocaine hydrochloride alone offers effective pain relief with minimal systemic risks but might lack the extended duration and hemostasis benefits of epinephrine. The lidocaine-epinephrine combination provides prolonged anesthesia and reduced bleeding, but clinicians must balance these advantages with the potential for ischemic events and delayed wound healing. Close monitoring, precise dosing, and careful patient selection are paramount in ensuring successful outcomes while minimizing complications. Further research is warranted to refine guidelines and enhance our understanding of the optimal anesthetic approach in these delicate surgical settings.

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