Epinephrine in Digital Nerve Blocks: Medical Mistake or Evidence-Based Practice?

Joseph A. Andrews BHSc, MD Candidate, Faculty of Medicine, University of Alberta, Edmonton, Alberta

Abstract

Ring blocks are an important component of pain management following digit injury. It has long been believed and taught throughout medical school and post-graduate education that the use of epinephrine must be avoided in digital ring blocks. For most part, this dogma is rooted in historical inaccuracies obtained during the initial development of local anaesthetics in the late 19th and early 20th centuries. Analysis of 50 case reports of digital necrosis after ring blocks reveals confounding factors such as procaine acidity, use of tourniquets, infection, and overuse of anesthesia as likely causes of necrosis. Furthermore, analysis of over 200,000 cases of epinephrine ring blocks failed to identify a single case of digital necrosis. At the physiological level, epinephrine causes vasoconstriction in the digits by binding to adrenergic receptors. However, necrosis does not occur due to the resilience of digits to short-term ischemia. Consequently, use of epinephrine in ring blocks represents best practice because it decreases the time for anesthetic to work, prolongs the anesthetic effect, and produces hemostasis.

Local Anesthetic History

In the medical profession, there exists a belief that epinephrine should be avoided when providing anaesthesia to end arteries, such as in digital ring blocks, because of possible necrosis caused by vascular insufficiency. Much of this dogma is based on historical inaccuracies obtained during the initial development of local anaesthetics.

In 1884, Karl Koller documented the first use of local anesthesia by applying cocaine in the eye.[1] That year, Burke discovered that injecting cocaine into a finger could produce enough anesthesia to allow for simple surgical procedures of the affected finger.[2] Twenty years later, a German surgeon Heinrich Braun discovered that addition of epinephrine to cocaine produced a local anesthesia that lasted longer and resulted in less hemorrhage from the surgical incision.[3] However, after nearly a decade of experimenting with epinephrine anesthesia in digits, Braun expressed concern that elevated levels of epinephrine could impair blood flow and result in gangrene.[4]

Soon after, the first case of gangrene was reported.[5] In the following decades, several more case reports suggested that epinephrine in digital ring blocks caused gangrene.[6-8] Then in 1944 Bunnell suggested in his textbook, *Surgery of the Hand*, that epinephrine should not be injected into digits as it can cause gangrene.[9] From 1944 onwards, the use of epinephrine in digital blocks was considered a form of medical malpractice. Until recently, some textbooks still advised against the use of epinephrine despite comprehensive studies suggesting otherwise.[10] This article provides a historical overview of studies performed over the last two centuries on epinephrine safety in digital ring blocks.

Case Reports of Digital Necrosis

Through an extensive 120-year review of medical publications, Denkler identified 48 documented cases where local anesthetic applied to a digit caused gangrene.[11] In a similar study, Krunic identified 50 cases.[12] Of these cases, only 21 used epinephrine, and in each of these 21 cases, at least one of several problematic features that could cause necrosis was present.

For instance, the concentration of epinephrine injected was known in only four cases. The remaining 17 cases occurred more than sixty years ago, before standardized commercial dilution techniques, so it is possible that exponentially larger doses of epinephrine than what is used today were injected. Similarly, all the case reports used non-amino amide type anesthetics (cocaine and procaine) because lidocaine was not produced until 1948. Procaine is of particular concern because it acidifies as it ages.[13] Until 1978, the US Food and Drug Administration did not mandate expiration dates. Thus, a possibility exists that procaine with epinephrine solutions were highly acidic. Furthermore, experiments performed in the 1950s with old procaine solutions found in hospitals resulted in tissue necrosis when injected in rabbits.[14]

Denkler and Krunic identified mechanical problems involved in the surgical procedure as another problematic feature.[11,12] For instance, two cases involved excessive amounts of anesthetic, which could have resulted in bilateral damage of the blood vessels.[15,16] In 14 cases, hot soaks applied after the surgical repair of the digit resulted in burns that damaged the tissue. Additionally, tourniquets, which can damage vasculature and muscle,[17] were applied in four cases on the digit to restrict the blood flow. Finally, in 14 cases there was evidence to suggest infection of the digit.

Corresponding Author:
Joseph A. Andrews
E-mail: jaandrew@ualberta.ca

The cases reviewed by Denkler and Krunic do not support the conclusion that epinephrine alone causes digital gangrene due to incomplete data and confounding factors such as procaine acidity, use of tourniquets, infection, and overuse of anesthesia.

Epinephrine Safety

Since the 1950s, numerous studies on epinephrine safety in ring blocks have been performed. However, many of these studies were retrospective. Additionally, several randomized control trials for digital anesthesia with and without lidocaine have also been performed. Table 1 provides a summary of these studies. Of the 200,000 cases where anesthesia with epinephrine was used, not a single case of digit necrosis was reported.

After examining the evidence for epinephrine in causing digital necrosis, a question arises: Is there a benefit to using epinephrine in digital blocks? The answer is yes, there are several advantages.

First, the vasoconstrictive properties of epinephrine reduce the absorption rate of the anesthetic from the interstitial tissue to the bloodstream.[29] This reduced absorption rate means a larger volume of lidocaine with epinephrine is required before lethal levels of lidocaine accumulate in the blood. Second, the use of epinephrine decreases the time for the anesthetic properties to take effect.[23, 28] Finally, epinephrine reduces blood flow during repair of lacerations or other open surgical procedure in the digits. Thus, tissue damage from a tourniquet is avoided and better visualization of the anatomy for surgical repair is achieved via a reduction in blood flow.

In summary, the use of epinephrine in ring blocks is safe and advantageous because it prolongs the anesthetic effect, reduces the time to reach anesthesia, increases the volume of lidocaine required to cause toxic injury, and provides hemostasis.

Physiology & Pathophysiology

Although aforementioned studies provide compelling evidence for the efficacy and safety of epinephrine, the physiological reason why epinephrine does not cause digital necrosis must be explored. The following section provides a brief overview of the physiology behind epinephrine's action in ring blocks.

When introduced subcutaneously in the digits, epinephrine is one of the most potent vasoconstrictors. Its mechanism of action involves nonspecific binding of adrenergic receptors. Within digital blood vessels, epinephrine binds alpha-1 receptors located more distally as well as to alpha-2 receptors proximally.[12] This results in vasoconstriction primarily through constriction of arterioles and pre-capillary sphincters.[29] Within skeletal muscles of the digits, there are opposing vasoconstriction and vasodilation events occurring at the same time. Activation of alpha-1 receptors induces vasoconstriction, whereas activation of beta-2 receptors in digital muscles causes opposing vasodilation.[29] Within digits the alpha-1 receptor response dominates. Consequently, a reduction in blood flow occurs in digits due to a net vasoconstriction in both the muscle and skin.

Since epinephrine is such a potent vasoconstrictor, many opponents to its use suggest it can cause necrosis in the digits by completely blocking blood flow. Using colour Doppler ultrasonography, Altinyazar measured arterial blood flow in patients undergoing a digital block using 2% lidocaine with 1:100,000 epinephrine.[25] Findings from the study indicated that a significant decrease in blood flow occurred 10 minutes after injection in all patients. Notably, there was a complete cessation of blood flow occurring at 10 minutes in some patients. Within 60 to 90 minutes of initial injection with epinephrine and lidocaine complete blood flow was restored in all patients. With 90 minutes of ischemia, it would be expected that nerve, tendon, and muscle damage would occur, resulting in necrosis. However, in extreme cases digits are able to withstand ischemia for up to 42 hours, as is the case with accidental amputations, and provide normal functioning when replanted.[30] More specifically, based on accidental amputations, it is estimated that in digits muscle can withstand ischemia for 4 hours, nerve for 8 hours, fat for 13 hours, skin for 24 hours, and bone for up to 4 days.[31]

Interestingly, it appears that epinephrine, in some cases, causes complete ischemia of the digits during a ring block via binding of adrenergic receptors. However, necrosis does not occur due to the resilience of digits to short-term ischemia.

Table 1. Studies of epinephrine use in digital blocks and surgeries

Publication	Publication Year	Concentration of Epinephrine	Anesthetic Expiration Date Known	Number of Cases	Cases with Necrosis
Burnham[18]	1958	1:200 000	No	93	0
Johnson[19]	1967	1:200 000	No	98	0
Steinberg[20]	1971	1:100 000 – 1:200 000	No	200 000	0
Syladis[21]	1998	1:80 000	Yes	100	0
Wilhelmi[22]	1998	1:200 000	Yes	23	0
Wilhelmi[23]	2001	1:200 000	Yes	31	0
Andrades[24]	2003	1:100 000	Yes	25	0
Altinyazar[25]	2004	1:100 000	Yes	24	0
Lalonde[26]	2005	1:100 000	Yes	3110	0
Sonmez[27]	2008	1:80 000	Yes	10	0
Chowdhry[28]	2010	1:100 000	Yes	1111	0

Recommendations

As discussed, no single case of digital necrosis can be exclusively ascribed to the use of epinephrine in ring blocks. Instead, other confounding factors such as expired procaine, hot soaks, improper surgical techniques, infection, and mechanical tourniquets may be at fault in the cases of digital gangrene. Additionally, recent retrospective and double-blind studies failed to identify a single case of digital necrosis as a result of ring blocks using lidocaine with epinephrine. However, proper precautions and surgical procedures should be used when applying a digital ring block.

The following recommendations provided by Krunic and Denkler offer an excellent guideline to administering lidocaine with epinephrine for ring blocks:[11-12]

1) Use lidocaine with epinephrine 1:100,000 or less
2) Add 8.4% sodium bicarbonate in 1:10 ratio to prevent acidosis by buffering the solution
3) Use an anatomically correct approach with a 30-gauge needle
4) Inject 1.5 mL of anesthetic per nerve
5) Block nerves at metacarpal head
6) Phentolamine injections can be applied to reverse epinephrine if ischemia lasts for protracted time period
7) Avoid using epinephrine in vascular compromised patients including the following: Buerger's disease, Raynaud phenomenon, diabetes, scleroderma, or sclerodactyly.

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