A Multicenter Prospective Study of 3,110 Consecutive Cases of Elective Epinephrine Use in the Fingers and Hand: The Dalhousie Project Clinical Phase

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Purpose: To examine prospectively the incidence of digital infarction and phentolamine rescue in a large series of patients in whom local anesthesia with adrenaline was injected electively into the hand and fingers. There continues to be a commonly held belief that epinephrine injection is contraindicated in the finger despite a lack of valid evidence to support this concept in the literature.

Methods: From 2002 to 2004 there were 9 hand surgeons in 6 cities who prospectively recorded each consecutive case of elective hand and finger epinephrine injection. They recorded each instance of skin or tissue loss and the number of times phentolamine reversal of adrenaline vasoconstriction was required.

Results: There were 3,110 consecutive cases of elective injection of low-dose epinephrine (1: 100,000 or less) in the hand and fingers and none produced any instance of digital tissue loss. Phentolamine was not required to reverse the vasoconstriction in any patients.

Conclusions: The true incidence of finger infarction in elective low-dose epinephrine injection into the hand and finger is likely to be remote, particularly with the possible rescue with phentolamine. (J Hand Surg 2005;30A:1061–1067. Copyright © 2005 by the American Society for Surgery of the Hand.)

Key words: Epinephrine, infarction, hand, finger, elective.

There continues to be a commonly held belief[1] that epinephrine injection is contraindicated in the finger for fear of digital infarction caused by irreversible vasospasm. When the citations in modern textbooks are followed to their source, they reference generations of earlier texts or reports that end up citing the source of the belief: 21 anecdotal case reports of procaine or cocaine with adrenaline injections involved in digital infarction, most of which occurred before 1950.[2] Two recent independent in-depth reviews[2,3] of the evidence for the antiadrenaline dogma have concluded that it lacks validity. The reviews[2,3]

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also note that there is no valid evidence to support the concept that lidocaine with adrenaline in the finger is unsafe because there is not a single case report of digital infarction with lidocaine and low-dose (1: 100,000) adrenaline.

This controversy is important because elective adrenaline hemostasis allows an increasing number of hand surgeons to perform an increasing number of hand surgeries such as Dupuytren's contracture, flexor tendon repair, surgical reduction of finger fractures, and so forth under pure local anesthesia without a tourniquet and without an anesthesiologist.

This report is one component of the clinical phase of the Dalhousie project. The purpose of the Dalhousie project is to evaluate various aspects of the elective use of epinephrine in finger and hand surgeries. In 2003 the Dalhousie project experimental phase[4] showed that it takes an average of 6 hours and 20 minutes for adrenaline-injected fingers to return to the same color as noninjected fingers in the same hand. Each finger in that study was injected in the middle phalanx, in the proximal phalanx, and in the distal palmar crease so that both neurovascular structures were bathed with epinephrine at 3 levels. That same study showed that this process consistently and reliably was sped up to an average of 1 hour and 25 minutes after the injection of phentolamine, the epinephrine antagonist.

There are a number of retrospective and small-series reports[5–11] of surgeons using adrenaline safely in the digits. The clinical phase of the Dalhousie project documented the incidence of digital infarction in a large prospective multicenter series of consecutive cases of elective use of adrenaline in the finger and hand.

Materials and Methods

After obtaining institutional review board approval for this study 9 hand surgeons in 6 cities began prospectively keeping accurate records of cases in which they previously had been using elective epinephrine routinely for years.

From July 2002 to July 2004 they recorded each patient's procedure; age; which anesthetic agent was used with the epinephrine (lidocaine or bupivicaine); the occurrence of digital infarction, skin necrosis, or tissue loss of any kind; whether the adrenaline was injected into the hand or finger; and whether phentolamine was required to reverse adrenaline vasoconstriction for all of their consecutive cases of elective hand and finger epinephrine injections. Finger injection was defined as distal to the distal palmar crease on the palm, or distal to the metacarpophalangeal joint on the dorsum. In every one of our 1,340 finger-injection cases the epinephrine was injected immediately adjacent to the digital neurovascular bundles. In cases in which injections were performed both in the fingers and in the hand proximal to the fingers, they were counted as finger injections because the finger is more of an end-arterial blood supply than the hand. In patients in whom 2 or more fingers were injected with epinephrine it was counted as 2 or more injection cases.

Elective epinephrine injection was avoided in the uncommon situations in which patients might have had pre-existing significant problems with hand or finger ischemia such as previous finger infarction, severe acute crush, previous replantation, Buerger's disease, revision Dupuytren's surgery, severe vasospastic disorders, and so forth. Smokers, however, were not excluded unless they showed significant signs of finger ischemia.

The authors injected epinephrine electively into a total of 3,110 consecutive cases with 1,340 injections into the fingers and 1,770 injections into the hand. A total of 391 of the cases received epinephrine with bupivicaine and the rest received lidocaine. All of the cases were injected with a concentration of 1:100,000 or less of epinephrine. The authors were prepared to use phentolamine (1 mg/mL injected subcutaneously in the same places that the adrenaline had been injected) to reverse the epinephrine-induced vasoconstriction should this have been required.[4]

The average age of the patients was 53 years with a range of 1 day (amputation of floating fifth finger) to 93 years (pain with a carpal tunnel).

Because the main goal of this study was to examine the incidences of digital infarction and phentolamine rescue related to adrenaline in the hand and finger, issues such as outcomes of the various procedures performed are not addressed. None of the authors saw any difference, however, in the outcomes of procedures performed with adrenaline hemostasis from what they had seen with tourniquet hemostasis in their years of experience with both techniques.

Results

In all of the 3,110 cases of hand and finger injections there were no cases of finger infarction, skin necrosis, or tissue loss of any kind. There were no instances in which phentolamine had to be injected to reverse epinephrine-induced vasoconstriction.

The types of procedures and the locations of execution in which 1,340 fingers were injected are listed

Table 1. Finger Procedures with Elective Epinephrine Injection

Procedure	Clinic	Office	Main Operating Room	Emergency Department	Total
Trigger finger	207	169	52	0	428
Dupuytren's surgery	33	102	68	0	203
Finger amputations	73	0	9	18	100
Flexor tendon repair of finger	51	3	9	36	99
Surgical finger reduction	48	3	13	33	97
Excision of finger lesion	67	0	15	2	84
Extensor tendon repair	29	2	14	36	81
Digital nerve repair	23	4	10	17	54
Closed reduction of fracture	38	2	0	7	47
Tenolysis of finger	10	6	12	0	28
Repair of finger wound	9	0	7	12	28
Fusion of finger	9	0	14	0	23
Excision of finger ganglion	16	0	0	0	16
Removal of finger hardware	11	2	1	0	14
Mucous cyst excision	5	2	3	0	10
Incision and drainage of finger	3	0	0	5	8
Arthroplasty of finger	2	4	1	0	7
Foreign body removal in finger	3	0	0	1	4
Skin graft of finger	2	1	0	0	3
Thumb ulnar collateral ligament repair	0	0	3	0	3
Finger synovectomy	0	0	2	0	2
Tendon grafting	0	0	1	0	1
Total	639	300	234	167	1,340

in Table 1 and the procedures and locations for 1,770 hand cases are listed in Table 2.

The most common types of finger cases were 428 trigger-finger releases, 203 Dupuytren's contracture releases, 100 amputations, and 99 flexor tendon repairs (see Table 1 for the rest of the finger cases). Although most of the cases were surgical cases there were 47 cases of closed reductions of finger fractures.

The most common types of hand cases were 1,622 carpal tunnels, 32 closed reductions of metacarpal fractures, 24 ganglion excisions, and 18 basal joint arthroplasties. All of the cases were open surgeries except for the 32 closed reductions of metacarpal fractures (see Table 2 for the rest of the hand cases).

Tables 1 and 2 also show the location of the surgeries as clinic, office emergency room, or main operating room. This reflected a pattern of practice

Table 2. Hand Procedures with Elective Epinephrine Injection

Procedure	Clinic	Office	Main Operating Room	Emergency Department	Total
Carpal tunnel release	1,024	456	142	0	1,622
Closed reduction metacarpal	32	0	0	0	32
Excision of wrist ganglion	14	0	9	1	24
Trapezium arthroplasty	0	2	16	0	18
de Quervain's release	15	0	1	0	16
Excision of hand lesion	11	1	5	0	17
Tendon transfer	5	0	6	1	12
Open reduction internal fixation metacarpal	0	0	9	0	9
Flexor tendon repair	2	0	0	4	6
Skin graft of hand	2	0	1	2	5
Wound repair of hand	2	0	1	1	4
K-wire hand fracture	2	0	0	0	2
Remove hardware from hand	2	0	0	0	2
Digital nerve repair of hand	1	0	0	0	1
Total	1,112	459	190	9	1,770

that shifted many of the previously performed procedures from the main operating room into the clinic, office, and emergency room.

Discussion

This study reports 3,110 consecutive cases of low-dose elective adrenaline (≤1:100,000) injection into 1,770 hands and 1,340 fingers without a single case of digital tissue loss or infarction. Just as important, none of the cases required the injection of phentolamine to reverse the vasoconstrictive effect of the epinephrine.

The experimental phase of the Dalhousie project showed that phentolamine consistently and reliably reverses adrenaline vasoconstriction in the finger in an average of 1 hour and 25 minutes.[4] That study also showed that the vasoconstrictive effect of 1:100,000 adrenaline wears off by itself in an average of 6 hours and 20 minutes in the finger. There are at least 11 reports of phentolamine successfully reversing vasoconstriction in high-dose (1:1,000) accidental epinephrine finger injections.[12–22] Phentolamine rescue was not required in any of the 1,340 finger injections in the patients in this study, nor was phentolamine required in any of the other patients in the combined experience of the 9 authors of over 100 surgeon-years of adrenaline injection without tissue loss before the study. If there had been a significant ischemic event the authors most likely could have rescued the finger with phentolamine. These combined facts render the likelihood of a nonrescuable finger low-dose adrenaline-induced ischemic event remote.

We are not advocating the use of elective low-dose adrenaline injection for all patients. Although contraindications are not well established the use of elective low-dose adrenaline injection was avoided in significant pre-existing vascular deficiency of the fingers such as in patients with pre-existing digital gangrene, Buerger's disease, previous replantation, or in any patient with questionable pre-injection circulation. A concentration greater than 1:100,000 was not used. We cannot say that finger ischemia will never happen with low-dose epinephrine injection. With the massive number of digital blocks that are performed throughout the world on a daily basis someone is bound to infarct a finger that barely is alive by injecting it with epinephrine. We do believe that no one should inject a finger with epinephrine without the full knowledge of how to reverse adrenaline vasoconstriction with phentolamine,[4] just as no one should inject morphine without understanding naloxone rescue. We believe that the risk for infarction is extremely low in properly selected patients with good pre-injection finger circulation when performed by a physician who understands phentolamine rescue.

A line was drawn at the distal palmar crease to determine a finger injection instead of a hand injection because this is the level at which the digital arteries come off of the arch to become an end-artery system, and when adrenaline is injected at or distal to the distal palmar crease blanching frequently occurs beyond the web space and therefore the adrenaline has diffused beyond the web space.

In 1967 Johnson[5] reported 421 cases of adrenaline injection into the hand and fingers with no ill effects. Steinberg and Block[6] reported more than 200,000 injections with lidocaine with epinephrine at concentrations of 1:100,000 or less into the foot, forefoot, and toes without a single case of infarction. Sylaidis and Logan[7] used epinephrine at 1:80,000 concentration in 100 consecutive patients with no ischemic events. Denkler[8] reported Dupuytren's fasciectomies in 60 consecutive digits using lidocaine with epinephrine and no tourniquet with no resulting ischemia. There are other reports in the literature documenting the safety of low-dose epinephrine (≤1:100,000) in the finger.[9–11]

In 2005 Thomson et al[23] performed an in-depth analysis of all of the evidence that created the outdated dogma that epinephrine caused digital infarction. Their findings augmented that of others[2,3] that this evidence is not valid for 3 reasons. First, the 21 adrenaline digital infarction cases of the pre-1950s that created the dogma also were injected with either procaine or cocaine, which were known to cause digital infarction without adrenaline at that time. Second, none of the 21 adrenaline infarction cases had an attempt at phentolamine rescue because this drug was introduced for this purpose only in 1957.[24] Third, there are no documented cases of finger infarction with a known low dose (≤1:100,000) of epinephrine with lidocaine in the literature.

The advantages of elective epinephrine use in the hand and finger are notable. The main advantage is the deletion of the need for the tourniquet and therefore the deletion of the risks associated with sedation or general anesthesia for most hand surgeries. In older patients with medical problems needing Dupuytren's surgery, avoiding these risks can be very valuable. In addition these patients get to see their active range of pain-free motion at the end of the

procedure and they know how much they should be able to perform once the pain subsides after surgery.

The costs and conveniences of performing these procedures under pure local anesthesia also are improved remarkably. All of the cases in this series were performed under pure local anesthesia, without a tourniquet and without general anesthesia or sedation. As can be seen in Tables 1 and 2 only 142 of 1,622 carpal tunnel procedures and only 9 of 99 finger flexor tendon repairs were performed in the main operating room. This shift of practice has had a major cost reduction and increased convenience impact on the practice of the 9 surgeons who participated in this study.

There are several advantages of performing flexor tendon repair under pure local anesthesia. First, after the flexor tendon is repaired the awake unsedated patient actively can bring the finger through a full range of motion. This sometimes shows gapping in the repair that can be corrected before skin closure. Second, the finger range-of-motion exercise also can show impingement of tendon repair movement by dispensable cruciate pulleys that can be divided before skin closure. Third, with multiple tendon lacerations in spaghetti wrists the patient can help identify the proximal tendons by comfortably but actively pulling on them without a tourniquet. Fourth, the unsedated patient who is watching the procedure can be educated during surgery by the surgeon in an uninterrupted fashion for more than an hour about the details of tendon rupture, gliding, and the importance of postoperative care; thus the patient becomes a more educated partner having observed the tendon repair. Fifth, the clinic also provides a more conducive environment for hand therapists to observe surgery and have a visual image of the repair quality, the state of the pulleys, and the amount of active range of motion seen at the end of the procedure. Finally, there is no violent active jerking on a freshly repaired tendon as patients sometimes are prone to do when they wake from general anesthesia.

Tenolysis in the awake patient without a tourniquet is no longer a race against the clock with tourniquet time. The comfortable tourniquet-free patient can be instructed to pull on the flexor from time to time throughout the procedure. By pulling on the flexor the patient frequently pops the last little bit of adhesion.

In tendon transfers of the extensor indicis to the extensor pollicis longus we have observed that transfer tension can be adjusted so that it is neither too tight nor too loose as patients compare the active range of motion of both thumbs before the skin is closed.

With thumb and finger joint fusions the comfortably awake patient can try pinch and grip actively and see the result with temporary K-wires in place before committing the angle of the fusion with the final fixation.

The duration of anesthesia in fingers injected with a total of 5.4 mL of 2% lidocaine with 1:100,000 epinephrine lasted an average of 9 hours in the experimental phase of the Dalhousie project.[4] This variable was not measured in this clinical series but we believe that the timing is roughly the same.

Hand and finger surgery with epinephrine vasoconstriction is not as bloodless as with exsanguination and a tourniquet. We recommend waiting 30 minutes or more before incising to allow full adrenaline vasoconstriction effect. Some of the authors routinely inject 2 or 3 patients in the waiting area 1 hour before going into surgery and perform 1 case while the other is blanching. As with epinephrine injection in other parts of the body there still will be initial bleeding with skin incisions that usually will subside quickly. Cautery is not required for most procedures. We also recommend adrenaline injection wherever the incisions are going to be made, including the fingertip pulp, as we have performed on many occasions with no adverse effects to date. If there is no injected adrenaline where the cut will be made the incision certainly will bleed more.

The surgeons in this study did not detain patients routinely for monitoring the return of normal color to the adrenaline-blanched fingers. This 2-year prospective review encompasses their combined clinical experience of well over 100 surgeon-years of clinical experience with adrenaline in the fingers. This experience has taught them that there is almost always good flow in the fingertips at the end of the procedure, that this flow only will improve, and that monitoring likely is not any more necessary in the fingers than it is in adrenaline-injected noses or ears. Maneuvers such as warming solutions also are not necessary. Occasionally a finger has turned bluish; however, a good flow always returns to the finger within 2 to 3 hours. It probably is wise to monitor these latter patients until robust flow is seen once again in the fingertip. We now understand that these rare blue fingers are not in a no-flow state as they would be with a tourniquet. They are in a low-flow state and not completely ischemic.[25] Two or 3 hours of a low-flow state with adrenaline also is much less than

the time of total ischemia that can be tolerated with finger amputation and replantation.[26]

Most of the authors of this study use the dorsal block technique and therefore most of the cases in this study were performed with this technique. This technique deposits the local anesthesia around the digital neurovascular bundles. Some of the authors of this study use the volar midline subcutaneous injection digital block to avoid lacerating the nerves and arteries of the finger with the bevel of the needle. Even with the midline injection technique, however, it is evident at surgery that both digital arteries end up being bathed with adrenaline-containing fluid. Therefore it is clear that in all of our 1,340 finger injection cases the epinephrine was injected immediately adjacent to the digital neurovascular bundles. Despite this, in Dupuytren's surgery we frequently see digital artery pulsation in vessels bathed in epinephrine. This observation corroborates the study by Altinyazar et al[25] of epinephrine-injected fingers that found Doppler ultrasound–detectable blood flow in all but 4 of 24 patients. The flow restored itself in all 4 of their no-flow patients by 90 minutes, which is within normal general anesthesia tourniquet arm ischemia time.

Three of the authors likely inadvertently have injected digital arteries with adrenaline on at least 6 occasions. A transient (<1 h) instant blanching of the hemifingers or entire fingers was observed on those occasions but the fingers all turned pink in less time than the usual subcutaneous extravascular injections (6.5 h) without lasting effects. It is possible that the shorter duration time of vasoconstriction that was observed on these occasions may be related to the very short half-life of plasma epinephrine (1.7 min).[27]

The volume of local anesthesia used in the fingers in this study was not controlled because each of the 9 surgeons continued to use the volume of lidocaine with adrenaline that they had been using in their clinical practice for years before the study. In one of the author's (D.L.) 20 years of experience using lidocaine with (5 y) and without (15 y) adrenaline, he occasionally has seen temporarily blue fingers with both larger (8 mL) and smaller (2 mL) finger volumes of local anesthetic both with and without adrenaline.

Epinephrine loses potency in the injection bottles over time. To control for the possible loss of potency of the epinephrine all of the authors used premixed lidocaine with adrenaline, which comes with expiration dates to which they adhered.

Although this study was prospective, 1 limitation is that it was not randomized. To randomize these cases would have meant that the authors would have had to have a control group without epinephrine, which would have made surgery without general anesthesia and a tourniquet very difficult.

Epinephrine with lidocaine injection in well-vascularized hands and fingers by a physician who has proper knowledge about how to reverse vasoconstriction with phentolamine likely has a low risk for digital ischemia and infarction. It also has significant potential benefits associated with the deletion of the tourniquet and general anesthesia for many hand surgeries. Nevertheless all surgeons must exercise caution and be vigilant about accurate reporting of complications as we embark in this new direction in hand surgery.

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