Sonographically Guided Percutaneous First Annular Pulley Release

Cadaveric Safety Study of Needle and Knife Techniques

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Objective. The purpose of this study was to assess the safety of sonographically guided percutaneous finger and thumb first annular (A1) pulley releases performed using needle and hook knife techniques in an unembalmed cadaveric model. ***Methods.*** A single operator completed 50 (40 fingers and 10 thumbs) sonographically guided percutaneous A1 pulley releases in unembalmed cadavers using previously described needle and hook knife techniques and simulated local anesthesia. Half of the fingers and thumbs were completed with each technique. An experienced observer blinded to the technique dissected each specimen and assessed for neurovascular, flexor tendon, and A2 pulley injury. Completeness of release was also recorded as a secondary outcome. ***Results.*** No neurovascular or A2 pulley injury occurred in any digit, regardless of technique. No significant flexor tendon injury was seen in any digit, although minor surface scratches were visualized in 3 cases (6%; 2 knife and 1 needle). The hook knife technique was significantly more likely to result in a complete pulley release compared to the needle technique (22 of 25 [88%] versus 8 of 25 [32%]; $P < .001$). ***Conclusions.*** Sonographically guided percutaneous A1 pulley releases can be performed safely using previously described needle and hook knife techniques. The safety margin for thumb releases is less than that for finger releases, particularly with respect to the radial digital nerve. These cadaveric data support recently published clinical investigations recommending consideration of sonographically guided percutaneous A1 pulley release in the management of patients with a disabling trigger finger. ***Key words:*** digit; sonography; tenosynovitis; thumb; trigger finger.

Abbreviations
A1, first annular

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Trigger fingers are common causes of hand pain and disability, affecting 2.6% of the general population and 10% of diabetics during their lifetimes.[1–3] Most cases are idiopathic and present with variable degrees of finger pain, stiffness, catching (ie, triggering), and locking at the level of the distal palm.[2–5] Although the pathogenesis of trigger fingers is incompletely understood and potentially multifactorial, clinical symptoms most commonly result from a size mismatch between the first annular (A1) pulley and the underlying flexor tendons.[2–4,6–8] With respect to idiopathic cases, the primary pathoetiologic event appears to be the development of fibrocartilaginous metaplasia of the A1 pulley, which results in damaging frictional forces between the pulley and underlying flexor tendons.[3,6–8]

Symptomatic trigger fingers are typically treated nonsurgically with a combination of activity modification, splinting, physical therapy, and corticosteroid injections, yielding successful results in 60% to 92% of cases.[2,3,5,9–15] Open surgical release is indicated for refractory symptoms and is successful in 60% to 100% of patients.[2,12,16–26] Surgical complications include infection, weakness, digital nerve injury, stiffness, flexor tendon bow stringing, and scar tenderness and have been reported in up to 28% of cases.[2,4,12,16–19,20–29]

In 1958, Lorthioir[30] introduced a technique for percutaneous A1 pulley release using a specialized cutting device. Since that time, multiple clinical and cadaveric studies have described percutaneous A1 pulley releases using large-gauge needles, scalpel blades, or specially designed cutting devices.[4,10,18–21,31–49] Proposed advantages of percutaneous A1 pulley release include the ability to perform the procedure in an office setting, reduced procedural time and costs, faster recovery time, and the avoidance of a potentially painful palmar incision.[10,19,21,25,30,32,34,36,41,50,51] Although percutaneous release has resolved triggering in 74% to 100% of reported cases, continued safety concerns have likely impeded more widespread adoption of this procedure.[3,4,10,12,19,21,25,30–32,34,36,39–48,50–53] Sonographic guidance can potentially address these safety concerns through direct visualization of "at-risk" structures.[25,51] In the only two published clinical studies to date, sonographically guided percutaneous A1 pulley release completely resolved triggering in 98% of 142 digits (including 59 thumbs) at a minimum of 6 to 9 months of follow-up.[25,51] Although no major complications were reported in either of these investigations, limited anatomic data exist pertaining to the safety of this procedure in terms of digital nerve, flexor tendon, or A2 pulley injury.[25,50,51,53] Two published cadaveric studies examining the results of a total of 68 sonographically guided percutaneous releases yielded conflicting safety results and have limited clinical applicability due to methodological shortcomings.[50,53] The larger investigation (50 digits, including 10 thumbs) used embalmed cadavers; the smaller investigation did not include thumbs (18 fingers); and neither study included the use of potentially anatomy-altering local anesthesia.[50,52,53]

The primary purpose of this investigation was to assess the safety of sonographically guided percutaneous finger and thumb A1 pulley releases performed by an experienced operator using two different techniques (needle and knife) in an unembalmed cadaveric model, including the use of "local anesthesia" to simulate clinical conditions. Primary safety end points included the frequencies of digital neurovascular bundle, flexor tendon, and A2 pulley injuries, as well as the distances between the pulley cuts and the digital neurovascular bundles. A secondary purpose was to determine the frequencies of complete versus incomplete A1 pulley releases performed with the needle and knife techniques. We hypothesized that neither technique would result in damage to the neurovascular bundles as determined by dissection. Furthermore, both techniques would completely release 100% of the A1 pulleys while sparing the A2 pulleys and avoiding major tendon laceration.

Materials and Methods

General

The primary author (J.S.) completed 50 (40 fingers and 10 thumbs) sonographically guided percutaneous A1 pulley releases on 10 unembalmed cadaveric upper limb specimens using either a modified 19-gauge needle (needle technique) or a commercially available hook knife (knife technique).[4,25,35,46] At the time of the investigation, the primary author had more than 6 years of experience performing musculoskeletal sonography, including prior clinical experience using the needle technique and cadaveric experience using both the needle and knife techniques. A computer-generated balanced randomization scheme ensured that half of the fingers and thumbs were completed with each technique. The other primary investigator (M.R.), a fellowship-trained hand surgeon blinded to the release technique for each digit, subsequently dissected each specimen for the purpose of data collection. All procedures were completed in the Mayo Clinic Procedural Skills Laboratory, and cadaveric specimens were obtained through the Department of Anatomy's Mayo Foundation Bequest Program.

All specimens were free from signs of trauma, deformity, or surgery and had normal A1 and A2 pulleys as determined by preinvestigation sonographic examination.[7,54,55] The project was approved by the Mayo Clinic's Biospecimens Subcommittee of the Institutional Review Board.

Equipment

All procedures were performed using an iU22 ultrasound machine fitted with either a 17–5 MHz transducer with a 43-mm footprint or a 15–7 MHz transducer with a 30-mm footprint (Philips Healthcare, Bothell, WA). Needle releases were completed using a modified 19-gauge 38-mm stainless steel needle according to the technique of Rajeswaran and colleagues,[25] and knife releases were completed with a commercially available stainless steel hook knife (HAKI knife; BK Meditech, Inc, Seoul, Korea; Figure 1).[4,35,46]

Relevant Sonographic Anatomy

The normal A1 pulley can be visualized at the metacarpophalangeal joint, appearing as a uniform hyperechoic (or hypoechoic because of anisotropy) fibrillar thickening of the flexor tendon sheath (Figure 2).[7,49,50,55,56] The normal A1 pulley has a mean thickness of 0.5 mm (range, 0.4–0.6 mm) on both long- and short-axis views and is approximately 1 cm (9.8–10.2 mm) in length.[7,34,49,50,55] The A2 pulley can be identified in a long-axis view as a thin (0.3–0.5 mm) hyperechoic (or hypoechoic because of anisotropy) thickening of the flexor tendon sheath overlying the proximal third of the proximal phalanx, with a mean length of 16.3 mm (15–19 mm; Figure 2).[54,55,57] The finger digital nerves and vessels can be identified coursing lateral to the flexor tendons, the nerves lying palmar to the vessels (Figure 2).[25,42,51,54] The thumb radial digital nerve travels ulnar to radial across the flexor pollicis longus tendon an average of 12.5 mm (7–16 mm) proximal to the proximal A1 pulley.[28,32,36,43,50]

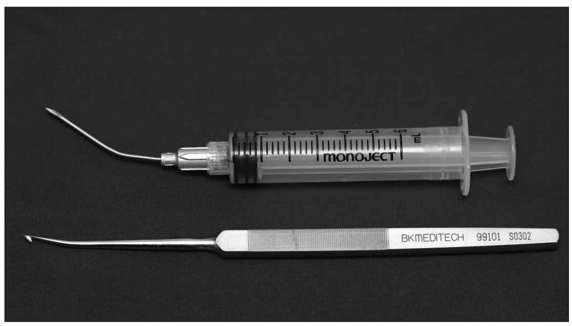
Sonographically Guided Percutaneous A1 Pulley Release Techniques

The hand and forearm were positioned in supination, and the target digit was held in hyperextension to dorsally displace the neurovascular bundles, providing a more parallel arrangement between the transducer, tendon and pulley, and cutting device (ie, needle or knife).[10,16,33,41,42,43] The pinky and index fingers were slightly abducted to reduce the risk of ulnar and radial digital nerve injury, respectively.[20,36,41,43,49,58] The transducer was placed longitudinally over the metacarpophalangeal joint.[30,37,42,50,51] From this position, and using long- and short-axis views, all relevant structures were identified. The transducer was then moved over the A1 pulley, long axis to the tendons, providing a sonographic view of the proximal-distal extent of the pulley. The midline of the A1 pulley was then identified using orthogonal short-axis views.

Local anesthesia was simulated with a 25-gauge 50-mm stainless steel needle inserted at the proximal finger creases and 1 cm distal to the proximal thumb crease, oriented in a distal-to-proximal direction.[10,35,46,50,51] The distal insertion

Figure 1. A, Modified 19-gauge 38-mm stainless steel needle used for needle releases (top) and commercially available hook knife used for knife releases (HAKI knife; BK Meditech). **B**, The needle shaft is bent to position the cutting edge of the bevel in a sagittal plane (top). The tip of the HAKI knife is pointed to facilitate passage through the subcutaneous tissues, whereas the downward-facing cutting blade is positioned just proximal to the proximal edge of the A1 pulley.

A



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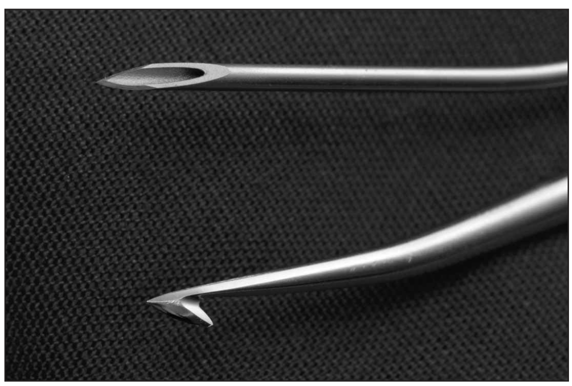
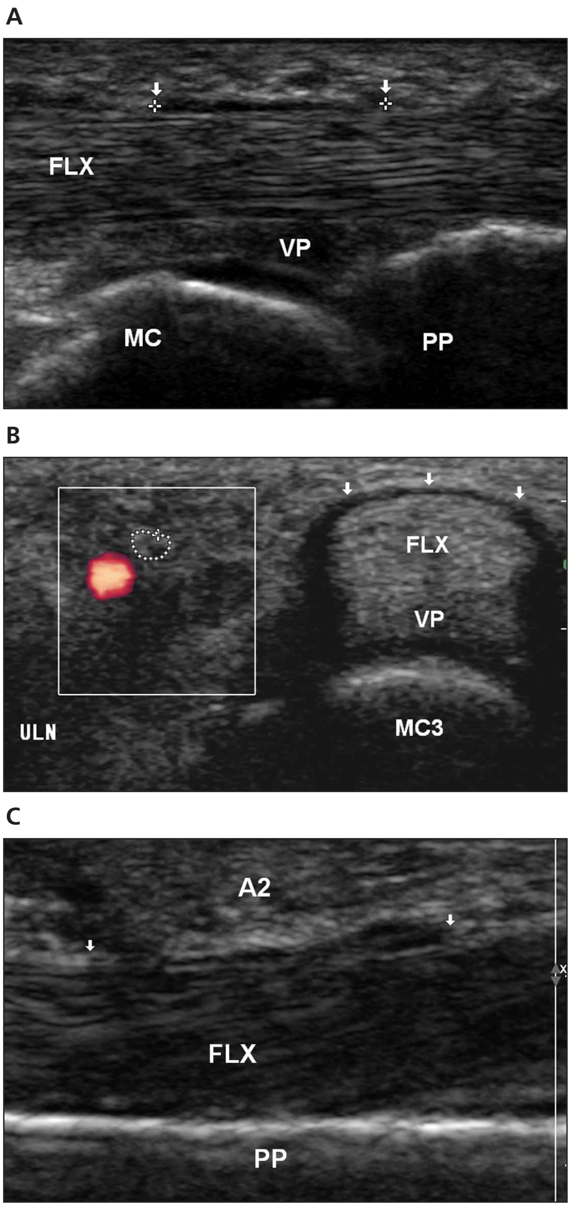


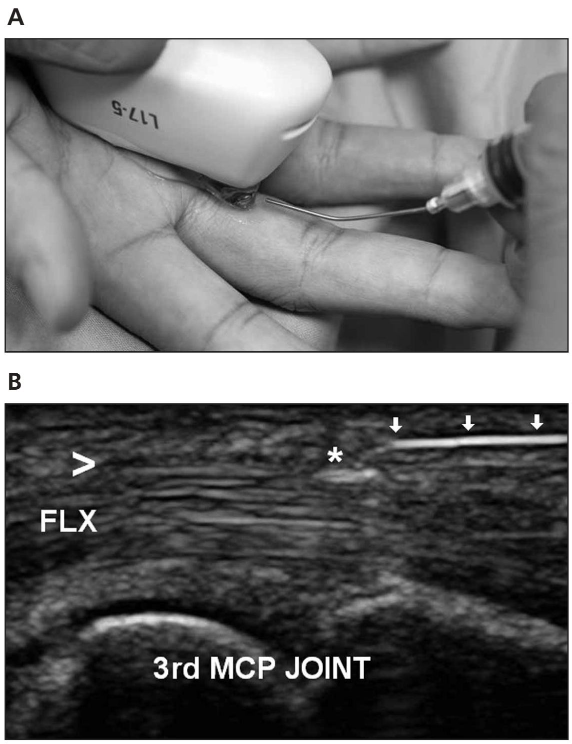
Figure 2. A, Long-axis view of the flexor tendons (FLX) showing the A1 pulley at the level of the third metacarpophalangeal joint. The proximal and distal ends of the thin hypoechoic pulley are identified by the vertical arrows. MC indicates metacarpal head; PP, proximal phalanx; and VP, volar plate. Left is proximal; right, distal; top, superficial; and bottom, deep (iU22; Philips Healthcare). **B**, Short-axis view of the flexor tendons using power Doppler imaging, obtained at the level of the A1 pulley. The hypoechoic A1 pulley (arrows) encircles the flexor tendons and attaches in part into the volar plate. Note the ulnar digital nerve (dotted circle) and artery (color). MC3 indicates third metacarpal head. Left is ulnar (ULN); right, radial; top, superficial; and bottom, deep (iU22; Philips Healthcare). **C**, Long-axis view of the flexor tendons showing the A2 pulley at the level of the proximal phalanx (PP). Vertical arrows indicate the proximal and distal ends of the A2 pulley. Note that the pulley is hypoechoic and slightly thicker distally than proximally. Left is proximal; right, distal; top, superficial; and bottom, deep (iU22; Philips Healthcare).



allowed simultaneous sonographic visualization of both the needle and A1 pulley while providing sufficient room for needle maneuvering. Under direct sonographic guidance, approximately 3 mL of water was delivered subcutaneously and around the pulley.

Needle releases were completed using the bent needle technique reported by Rajeswaran and colleagues,[25] adopted from Eastwood et al.[42] After local anesthetic infiltration, the modified 19-gauge needle was inserted through the same puncture site as the local anesthetic needle (Figure 3). The needle was advanced into the pulley under direct sonographic guidance, and the release was completed using a to-and-fro sawing

Figure 3. A, Hand, transducer, and needle positioning for sonographically guided percutaneous A1 pulley release using the needle technique. Note the needle entry point at the level of the proximal finger crease for release of the middle finger. **B**, Long-axis view of the middle finger flexor tendons (FLX) showing the A1 pulley at the metacarpophalangeal (MCP) joint. The needle tip is passed just under the distal edge of the A1 pulley (asterisk). The A1 pulley appears hypoechoic because of anisotropy. Note the fibrillar echo texture of the underlying flexor tendons as well as the bony contours of the metacarpal head and proximal phalanx. Open arrowhead indicates proximal margin of the A1 pulley; and vertical arrows, needle shaft. Left is proximal; right, distal; top, superficial; and bottom, deep (iU22; Philips Healthcare).



action combined with tip elevation away from the underlying flexor tendons.[25] The needle position was closely and continually monitored using long- and short-axis views to maintain the midline and avoid the digital nerves. The procedure was considered complete when the A1 pulley was discontinuous as visualized sonographically; the gritty feel of the A1 pulley could no longer be appreciated; the needle could be passed relatively unimpeded from the tendon into the subcutaneous tissues (ie, no perceptible intervening pulley); and the full length of the A1 pulley had been treated as determined by sonographic visualization and extension of the release from 1 to 2 mm proximal to the metacarpal head-neck junction to 1 to 2 mm distal to the proximal phalangeal base-shaft junction.[6,25,33,34,36,42,50,51,53] When treating the thumb, the radial digital nerve was sonographically identified as it crossed the flexor pollicis longus, and its position was marked with an indelible ink marker to avoid injury.[10,28,32,50]

Knife releases were completed using a HAKI knife with a 12° curved blade according to the previously described percutaneous technique of Park and colleagues, adapted for use with sonographic guidance.[4,35,46] After local anesthesia, the knife was advanced along the local anesthetic needle path, just superficial to the flexor tendon sheath, until the downward-facing cutting blade of the HAKI knife passed just proximal to the proximal edge of the A1 pulley (Figure 4). Once the knife position was confirmed, the blade was angled downward (ie, deep) to engage the proximal pulley and the HAKI knife was pulled distally to complete the transection. The cutting blade's position was closely and continually monitored using long- and short-axis views to maintain the midline and avoid the digital nerves. Criteria for completion of the knife release were similar to those for the needle releases.

Assessment

All digits were dissected and assessed by a fellowship-trained hand surgeon (M.R.), who was blinded to the release technique, and assisted by loupe magnification and a study coinvestigator (J.K.L.). Meticulous dissection ensured minimal disruption of normal relationships between the

Figure 4. A, Hand, transducer, and knife positioning for sonographically guided percutaneous A1 pulley release using the knife technique. Note the knife entry point at the level of the proximal finger crease for release of the middle finger (HAKI knife; BK Meditech). **B**, Long-axis view of the middle finger flexor tendons (FLX) showing the A1 pulley at the metacarpophalangeal joint (MCP JT). The knife tip is passed within the subcutaneous tissues to a point just proximal to the proximal edge of the A1 pulley (left arrowhead). The knife shaft and proximal tip are visualized as smooth curvilinear hyperechogenicity (vertical arrows). The proximal knife tip provides the position of the downward facing cutting blade, which is obscured by posterior acoustic shadowing. Right arrowhead indicates distal edge of the A1 pulley. Orientation is similar to Figure 3B (iU22; Philips Healthcare). **C**, Correlative short-axis view of the flexor tendons from B showing the hyperechoic tip of the HAKI knife at the level of the A1 pulley (asterisks). MC 3 indicates third metacarpal head. In this out-of-plane view of the HAKI knife, the tip appears as a hyperechoic dot. Left is radial (RAD); right, ulnar; top, superficial; and bottom, deep (iU22; Philips Healthcare).

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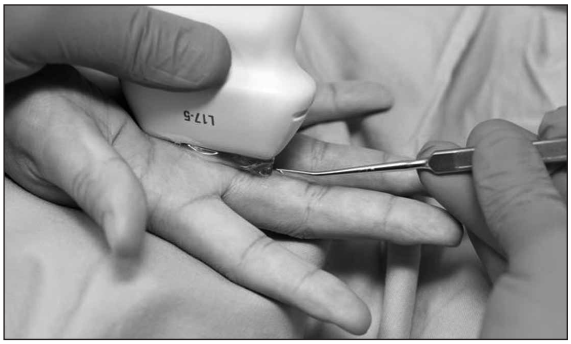

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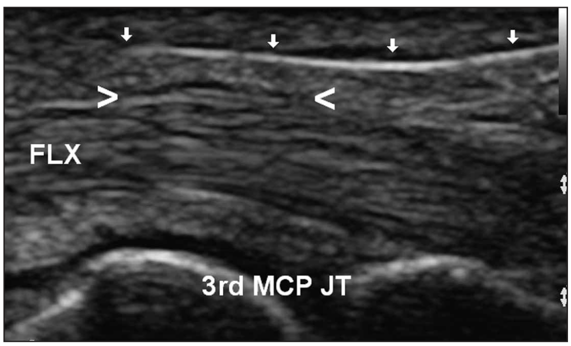

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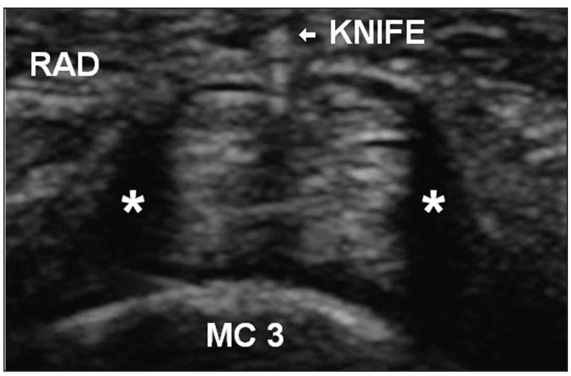


structures of interest.[37] For each digit, the following data were recorded: the cut location by gross inspection (midline, ulnar, radial, or oblique), the presence of digital neurovascular injury (yes or no for ulnar and radial sides), the closest measured transverse distance from the release cut to the radial and ulnar digital nerves as measured with a flexible tape measure (millimeters), the measured longitudinal distance between the proximal end of thumb releases and the crossover of the thumb radial digital nerve (millimeters), the presence of tendon injury (none, minor = minimal surface abrasion or excoriation affecting <5%–10% of tendon thickness, or major = visualized laceration affecting >5%–10% of tendon thickness or injury judged to be potentially clinically important), and the presence of A2 pulley injury (yes or no; if yes, what percentage of length). The frequency of complete releases was assessed as a secondary end point of the investigation. Complete releases were determined by dissection to have completely transected the A1 pulley, whereas incomplete releases contained intact tissue at the proximal or distal edge of the pulley.

Statistics

Descriptive statistics were used to report categorical data. Statistical analysis of needle versus knife techniques when comparing the cut distance to the digital nerves was completed using the Wilcoxon rank sum test to compare the ordinal data (needle or knife) to the continuous data of the measured distances. The Fisher exact test for ordinal data was used to evaluate for statistical differences among ordinal data (frequency of complete versus incomplete releases, frequency of A2 pulley injury, and frequency of flexor tendon injury). The level of statistical significance was set at $P < .05$.

Results

Release Location and Safety

Dissection revealed no neurovascular injury in any of the 40 fingers or 10 thumbs, regardless of the technique. By gross inspection, 22 of 25 needle releases (88%) were considered midline, 1 (4%) radial of midline, and 2 (8%) oblique. Similarly, 22 of 25 of knife releases (88%) were considered midline, 2 (8%) ulnar, and 1 (4%) radial. Tables 1 and 2 show the measured distances between the A1 pulley cuts and the radial and ulnar digital nerves for the fingers and thumbs, respectively. As shown in Table 1, knife releases were generally more ulnar (ie, decreased cut-ulnar distance) than needle releases (mean ± SD, 3.7 ± 1.0 versus 4.2 ± 0.8 mm; $P < .05$). Although not shown in Table 1, only 3 of 40 finger releases (7.5%) were within 2 mm of the neurovascular bundle (1 knife release on a pinky, 1 needle release on a pinky, and 1 knife release on a ring finger). With respect to the thumbs (Table 2), the 5 knife releases were sig-

Table 1. Distance Between A1 Pulley Cut and Digital Nerves for Fingers (n = 40)

Technique	Radial Digital Nerve, mm	Ulnar Digital Nerve, mm
Needle	3.6 ± 0.9 (2.0–5.0)	4.2 ± 0.8 (3.0–6.0)
Knife	3.8 ± 1.3 (2.0–7.0)	3.7 ± 1.0 (2.0–6.0)[a]
Overall average	3.7 ± 1.1 (2.0–7.0)	3.9 ± 0.6 (2.0–6.0)

Values are mean ± SD (range).
[a]Statistically significant difference between needle versus knife ulnar digital nerve distances ($P < .05$).

Table 2. Distance Between A1 Pulley Cut and Digital Nerves for Thumbs (n = 10)

Technique	Radial Digital Nerve, mm	Ulnar Digital Nerve, mm
Needle	2.6 ± 0.6 (2.0–3.0)	3.8 ± 0.8 (3.0–5.0)
Knife	1.9 ± 0.2 (1.5–2.0)[a]	3.8 ± 0.6 (3.0–4.0)
Overall average	2.2 ± 0.5 (1.5–3.0)	3.8 ± 0.6 (3.0–5.0)

Values are mean ± SD (range).
[a]Statistically significant differences between knife versus needle radial digital nerve distances ($P < .05$).

nificantly closer to the radial digital nerve than the 5 needle releases (1.9 ± 0.2 versus 2.6 ± 0.6 mm; $P < .05$; Table 2). One knife release was less than 2 mm from the thumb radial digital nerve (1.5 mm), whereas the remaining 4 releases were 2 mm away from the nerve. In comparison, 3 of 5 needle releases were 3 mm away from the nerve, with the remaining 2 measuring 2 mm away from the nerve. However, no radial digital nerve injury was seen in any thumb specimen.

Dissection confirmed that the sonographically placed skin marking precisely identified the ulnar-to-radial crossing of the thumb radial digital nerve at the radial border of the flexor pollicis longus in all 10 specimens. The average distances between the proximal incision and the ulnar-to-radial crossover were 8.2 ± 2.9 mm (range, 5–12 mm) for the needle releases and 8.2 ± 2.7 mm (6–12 mm) for the knife releases.

No flexor tendon laceration or injury of suspected clinical importance was seen in any flexor tendon, although minor surface scratches were visualized in 3 cases (6%; 1 middle finger knife release, 1 pinky knife release, and 1 middle finger needle release; $P > .99$ for needle versus knife). Similarly, no A2 pulley injury was observed in any specimen, regardless of technique.

Success of A1 Pulley Release

As shown in Table 3, the knife technique was significantly more likely to result in a complete pulley release compared to the needle technique (22 of 25 [88%] versus 8 of 25 [32%]; $P < .001$). Qualitatively, complete needle releases were jagged edged, whereas incomplete releases consisted of multiple nearly confluent linear pulley perforations appearing like Swiss cheese. On the contrary, knife releases were generally discrete, linear, and smooth edged, including the 3 cases of incomplete releases (Figure 5).

Discussion

This study represents the first formal large-scale investigation documenting the safety of sonographically guided percutaneous A1 pulley releases performed using "local anesthesia" in an unembalmed cadaveric model. After release of 40 fingers and 10 thumbs using 2 different techniques (needle and knife), no neurovascular injury, major tendon laceration, or A2 pulley injury was observed in any specimen. These data serve as further confirmation of the proposed safety of sonographically guided percutaneous A1 pulley releases.[50,51]

Regardless of technique (needle versus knife), 88% of releases were considered midline at gross inspection, correlating with the prior report by Chern and colleagues[50] of midline or paramedian incisions in 90% of 50 cadaveric digits following sonographically guided release using a hook knife technique. Finger releases were located an average of 3.6 to 4.2 mm (range, 2–7 mm) from the digital nerves, without significant differences between techniques (Table 1). Only 3 of 40 fingers (7.5%) had a distance of 2 mm (1 pinky knife release, 1 ring finger knife release, and 1 pinky needle release). The lack of previously published quantitative anatomic data following sonographically guided percutaneous release precludes direct comparison of our data with prior investigations.[50,53] Paulius and Maguina[53] did not report quantitative anatomic data with respect to neurovascular bundle distances from pulley cuts, and Chern and colleagues[50] stated that there was always "a few millimeters between the lateral edge and the digital nerve" after sonographically guided release. However, our distances were slightly smaller than the 4- to 6-mm distances reported for both the radial and ulnar digital nerves following nonguided percuta-

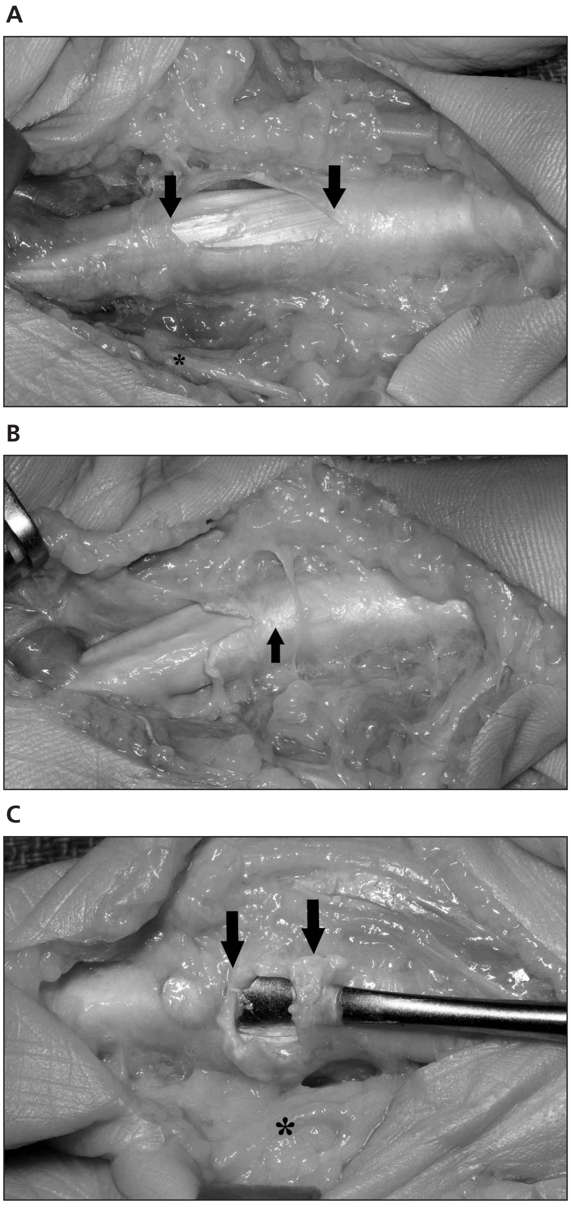
Table 3. Success of Sonographically Guided A1 Pulley Release (n = 50 Digits)

Technique	Complete	Incomplete Proximal	Incomplete Distal	Incomplete Proximal and Distal
Needle	8	5	5	7
Knife	22	2	1	0
Total	30	7	6	7

Knife statistically significantly greater frequency of complete releases versus needle (22 of 25 [88%] versus 8 of 25 [32%]; $P < .001$).

neous releases using needle techniques.[37,43] Because these small differences occurred on both the radial and ulnar sides, it is likely that these discrepancies reflect methodological differences among the studies (eg, measurement techniques, cadaver size, and preparation) rather than technical differences between sonographically guided and nonguided percutaneous techniques.[37,43] Although a larger margin of safety between releases and the neurovascular bundle would be desirable, a minimally acceptable "safe distance" has not been established, and no neurovascular injury was observed among the 40 fingers released in this investigation.

Figure 5. A, Dissection of complete middle finger A1 pulley release performed using the knife technique (arrows indicate proximal and distal edges). Note the smooth edges, lack of visible tendon injury, and the ulnar digital nerve (asterisk). Left is proximal; right, distal; top, radial; and bottom, ulnar. **B**, Dissection of incomplete index finger A1 pulley release performed using the needle technique. Release is incomplete distally (arrow). Orientation is similar to **A**. **C**, Cadaveric dissection of right index finger A1 pulley release using the needle technique. The distal pulley is completely released (left arrow), whereas the proximal pulley release is incomplete (right arrow). Note the typical irregular borders of the needle release, as well as the location of the ulnar digital neurovascular bundle (asterisk).



As reflected in Tables 1 and 2, the average cut-digital nerve distance was smaller for the thumb relative to the fingers, particularly with respect to the radial side. The cut-thumb digital nerve distance was within 2 mm in 2 of 5 thumb needle releases (40%) and 5 of 5 knife releases (100%), all occurring on the radial side. Not surprisingly, the average radial digital nerve distances were significantly smaller using the knife technique when compared to the needle technique. In comparison, using nonguided percutaneous needle release techniques, Bain and colleagues[43] reported a distance of less than 2 mm in 7 of 17 thumbs (41%), Pope and Wolfe[36] in 3 of 5 (60%) thumbs, and Schramm and colleagues[37] in none of 6 thumbs. Unlike prior investigations, our study also specifically examined the ability to sonographically identify the thumb radial digital nerve crossover and determine its position relative to the proximal aspect of the release.[28,50] In all 10 thumbs, the operator (J.S.) precisely identified the point at which the radial digital nerve passed beyond the radial extent of the flexor pollicis longus as determined by dissection. The distance between the proximal extent of the annular release and the crossover ranged from 5 to 12 mm, similar to the 7- to 16-mm range reported by Chern and colleagues.[50] Most published anatomic data suggest that percutaneous thumb annular pulley releases may have a lower margin of safety from a neurovascular standpoint.[28,30,32,36,37,43,52] However, this appears to be manageable because only a single nonpainful thumb radial digital nerve injury has been reported after nonguided percutaneous release, and no anatomic or clinical study to date has reported thumb digital nerve injury following sonographically guided thumb annular pulley release.[2,4,10,25,30,32,36,37,40,41,47,51] Although this investigation did not directly assess the relative risk of guided versus nonguided releases, the ability to precisely identify the thumb radial digital nerve in 10 of 10 specimens is reassuring and suggests a role for sonography in managing injury risk during percutaneous release.

No major tendon injuries were observed in any of the 50 releases performed in this investigation, although surface scratches were seen in 3 cases (6%; 1 middle finger knife release, 1 pinky knife release, and 1 middle finger needle release). None of these scratches were determined to be potentially clinically important by the assessor, a fellowship-trained orthopedic hand surgeon (M.R.). Avoiding flexor tendon injury during percutaneous release is desirable because deep tendon lacerations or flap tears may result in stiffness, pain, or triggering.[31,32,34,39,43,48,53] Comparison with prior anatomic studies following sonographically guided release is challenging because of variable definitions of tendon injury. Paulius and Maguina[53] reported "lacerations" in 3 of 18 tendons (17%), but no formal definition of laceration was provided. Chern and colleagues[50] found no notable injury in 50 digits (including 10 thumbs), defined as "no divided tendon, no full-layer longitudinal laceration, and no visible ruptured tendon." However, the authors did note "longitudinal splitting with surface scratches" in 3 of 50 digits (6%), similar to this investigation.[50] Overall, it appears that major tendon injury is at most uncommon following sonographically guided release, a conclusion supported by the lack of clinically apparent tendon injury following 142 releases in published clinical studies to date.[25,51]

It is important to minimize the risk of A2 pulley injury during percutaneous trigger finger release.[34,36,38,50] Flexor tendon bow stringing as a result of excessive A2 pulley injury (>25% of its length) is a well established, albeit uncommon, complication of open trigger finger releases.[12,16–20,27,29,49,58] Using sonographically guided percutaneous knife and needle techniques, we did not observe any A2 pulley injury in our 50 specimens. In comparison, Chern and colleagues[50] reported small (<2 mm, <20% of A2 pulley length) lacerations in 6 of 50 specimens (12%) following sonographically guided release using a hook knife technique. Three separate cadaveric investigations have reported no A2 pulley injuries following a total of 87 nonguided percutaneous A1 needle releases, whereas Dunn and Pess[34] reported minor A2 injuries (<20% of A2 pulley length) in 6 of 52 nonguided releases (11.5%) using a push knife technique.[34,36,38] On the basis of available anatomic data, the risk of major A2 pulley injury appears to be low using either sonographically guided or nonguided percutaneous techniques. In fact, we are unaware of any case of iatrogenic flexor tendon bow stringing following percutaneous A1 pulley release among published clinical studies.[3,4,10,18,19,20,25,30–36,44–48,51] Although high-frequency sonography can reliably identify the A1 and A2 pulleys in most individuals, it remains to be established whether sonography provides a greater margin of safety with respect to A2 pulley injury during percutaneous trigger digit releases.[54,55,57]

Although not a primary end point of this investigation, our techniques did not result in anatomically complete A1 pulley releases in all cases (Table 3). Knife releases were significantly more likely to be complete compared to needle releases. This finding is consistent with previously published data pertaining to sonographically guided percutaneous releases. Paulius and Maguina[53] observed that only 3 of 18 needle releases (17%) were complete, whereas Chern and colleagues[50] reported a 96% (48 of 50) rate of complete releases using a hook knife technique. On the basis of these limited data, it may be suggested that sonographically guided knife techniques result in more complete anatomic A1 pulley transections compared to needle techniques. However, clinicians should approach this conclusion with caution for two reasons. First, achieving anatomically complete A1 transection is more challenging in cadaveric specimens with normal pulleys compared to clinical patients with enlarged pulleys and clinical end points (ie, the resolution of triggering).[4,7,21,34,36,43,53,55] Second, near-complete anatomic releases may resolve triggering, and clinical studies of sonographically guided percutaneous releases have reported 100% resolution of triggering using either needle (35 digits) or knife (107 digits) techniques.[25,36,40,51] Although prospective comparative studies are lacking, sonographic guidance may enhance the ability to resolve triggering because nonguided percutaneous releases have required open conversion in up to 16% of cases in clinical series.[4,20,31,32,35,48]

Only one prior published investigation included percutaneous needle and knife A1 pulley releases completed by the same operators. Using nonguided techniques, Dunn and Pess[34] completed 52 push knife releases and 26 needle releases in unembalmed cadavers. Similar to our investigation, no neurovascular injury was observed in any specimen. Dunn and Pess[34] reported that compared to the needle technique, the push knife technique resulted in a significantly greater number of complete A1 pulley releases (51 of 52 [98%] versus 10 of 26 [38%]), significantly less moderate and severe flexor tendon injuries (0 of 52 versus 13 of 26 [50%]), and more A2 pulley injuries (6 of 52 [12%] versus 0 of 26). In comparison, neither the hook knife nor needle techniques used in our investigation produced any A2 pulley injury or major flexor tendon injury in any specimen. Similar to Dunn and Pess,[34] we also observed a higher frequency of complete releases using the knife technique compared to the needle technique (Table 3). In addition, we found that the needle releases, whether complete or incomplete, appeared ragged edged (Figure 5). On the contrary, 100% of the knife releases were sharp edged, whether complete or incomplete. Although one may hypothesize that the sharper knife cuts may reduce postprocedure pain, scarring, or recurrence, further clinical study is necessary before establishing these conclusions.[25,51] Our observation that finger knife cuts were more ulnar and thumb cuts more radial when compared to the needle cuts is intriguing (Tables 1 and 2). Although this may be a result of an interaction between the cutting device (bent needle versus knife), hand positioning, and transducer position, the explanation for this finding remains uncertain. Despite the observed statistically significant differences, the quantitative differences are small, potentially within measurement error, and are of unclear clinical importance. It was not the primary purpose of this investigation to determine the "best" method of sonographically guided percutaneous release. Consequently, on the basis of our results, we can only state that both techniques were "safe" according to our study criteria, with knife releases being more likely to be complete while producing sharper edges at the release site.

The current investigation has multiple strengths, including the following: (1) the inclusion of two different techniques (knife and needle) completed by a single experienced operator, (2) the use of a relatively large number of unembalmed cadaveric specimens, (3) simulation of potentially anatomy altering local anesthesia, (4) use of commercially available equipment, and (5) assessment by a fellowship-trained hand surgeon, blinded to the technique, using pre-established criteria. Nonetheless, several methodological limitations are worthy of discussion. First, it is possible that anatomic dissection altered the relationships between the releases and the digital nerves.[36,37,43] Although this may explain some of the variability in cut-digital nerve distances observed in this investigation relative to prior studies, it does not negate the finding that no neurologic injury occurred in any specimen in this investigation. Second, although we consider the use of a single operator a methodological strength of this investigation, we are unable to determine whether our results would be reproducible by examiners with different experience levels. Similar to prior authors, we agree that sonographically guided percutaneous release can be a technically challenging procedure accompanied by a steep learning curve.[4,25,41,43,46,50,51,53] Third, it is unknown to what extent the results of this cadaveric investigation on normal pulleys can be extrapolated to clinical patients with abnormal A1 pulleys. However, the need to identify a large number of abnormal A1 pulleys among cadaveric specimens essentially precludes performing a similar anatomic study on abnormal pulleys. Finally, because the primary focus of this investigation was on safety, we are unable to specifically comment on the relative ease of knife versus needle releases or the relative cost-effectiveness of each technique.

In conclusion, our data indicate that sonographically guided percutaneous A1 pulley releases performed using either needle or hook knife techniques appear to be safe when applied as outlined in this investigation. No neurovascular injury, major flexor tendon injury, or A2 pulley laceration occurred in 40 fingers and 10 thumbs, regardless of the technique. In conjunction with previously published anatomic and clinical studies, these results suggest that sonographically guided percutaneous releases are safe and should be considered in the treatment algorithm of trigger fingers. Further research may clarify methods to further increase the safety margin of sonographically guided percutaneous A1 pulley releases, particularly with respect to the thumb. In the meantime, we recommend practicing the procedure on cadaveric specimens, placing the target digit in full extension, sonographically identifying the thumb radial digital nerve, and avoiding a potential tendency for radial positioning during thumb releases.[10,16,28,32,33,36,41,42,43,50]

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