The Clinical Application of Kaplan's Cardinal Line as a Surface Marker for the Superficial Palmar Arch

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Abstract We feel the original description of Kaplan's cardinal line provides a more accurate reference point to the superficial palmar arterial arch. We sought to anatomically correlate the relationship of Kaplan's cardinal line to the superficial palmar arch. Sixty hands (30 cadavers) were dissected after Kaplan's original description was drawn on each hand. Measurements we made from Kaplan's cardinal line to the superficial palmar arch at both the radial and ulnar borders of the ring finger. The superficial palmar arterial arch was an average of 10.4 and 11.8 mm from the radial and ulnar borders of the ring finger with standard deviations of roughly 4 mm for each measurement. Clinically, Kaplan's cardinal line is a more predictable landmark for the superficial palmar arch. In referencing this landmark as the distal most extent of an open or endoscopic carpal tunnel release, the superficial palmar arch should be free of transection.

Keywords Kaplan's cardinal line · Carpal tunnel · Superficial palmar arch · Endoscopic carpal tunnel release

Introduction

Endoscopic and open carpal tunnel releases (CTR), even if performed meticulously, still carry the potential for complications. A survey of American Society for Surgery of the Hand (ASSH) members published in 1999 noted a myriad of injuries, including damage to the superficial palmar arch (SPA) in both types of releases [18]. The preciseness of the incision utilized is paramount in preventing iatrogenic injury and ensuring a good outcome. The limited visual field in CTR, more appreciable in the endoscopic method, attests to the importance of topographical markers to delineate underlying structures [18, 24]. Incisions can then be planned taking into consideration potential areas of neurovascular vulnerability.

Arguably, the most vulnerable structure during CTR is the SPA, the distal extent of the ulnar artery. Understanding the variability of the SPA and its anatomical relationships to overlying surface markers can ensure that skin incisions are made in relative "safe zones". Kaplan's cardinal line, originally described in 1953 by E.B. Kaplan (Fig. 1), is one of the more notable surface markers (original version, OKCL) [9]. Kaplan's description of his landmark was a line "drawn from the apex of the interdigital fold between the thumb and index finger toward the ulnar side of the hand, parallel with the middle crease of the hand" [9].

Based upon our clinical observations, we theorized that incisions for both open and endoscopic CTR should be limited distally by the intersection of a longitudinal incision with the original KCL (OKCL). This would ensure that inadvertent injury to the SPA would be avoided. A cadaveric study was thus undertaken to find the relationship of the intersection of OKCL and longitudinal lines along the radial and ulnar borders of the ring finger with the SPA. Our goal was to measure anatomically the distances

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Figure 1 Incision for open carpal tunnel release at the intersection of the proximal extension of the radial border of ring finger with the original description of Kaplan's cardinal line.

separating the distal extent of planned CTR incisions and the SPA, utilizing OKCL as a topographical marker.

Methods

Thirty undissected, embalmed cadavers (60 hands) were obtained with permission from a local medical school anatomy lab. The average age of the cadavers was 78.8 years (range 49–92). There were 18 females and 12 males in the group. Surface anatomic markers (palmar creases, first web space) were identified. The OKCL was demarcated, along with longitudinal lines corresponding to the radial and ulnar borders of the ring finger as these are most commonly described markers for CTR [7, 9] (Fig. 2). Soft tissue dissection was performed utilizing 2.5X Loupe magnification. The ulnar artery was identified at the level of Guyon's canal and traced distally to the takeoff point of the SPA. Completeness of the arch, variations, and anastomotic patterns were noted and recorded.

Using digital calipers (Digimatic Mycal E-Z Caliper, Mitutoyo Corp, Aurora, IL, USA), the distance between the SPA and the junction point of the OKCL and the longitudinal lines from the radial and ulnar borders of the ring finger was measured in each cadaveric hand (Fig. 3). The distances were averaged, and the standard deviation was determined.

Results

Various configurations of the SPA were noted in the dissections. Complete arches were noted in 44/60 hands (73.3%), with an incomplete SPA in the remaining 16

Figure 2 Cadaveric specimen showing OKCL intersecting with lines extending proximally from the borders of the ring finger. Note OKCL paralleling the middle palmar crease.

specimens. The radial artery was the major secondary contributor to the SPA in 30/44 (68%) cases where a complete arch was found. In four cases, there existed a median artery, which in all four cases traversed longitudinally in line with the long axis of the long finger to anastomose with the SPA distal to OKCL.

Distances from the intersection of OKCL (proximally) with the radial and ulnar borders of the ring finger to the most proximal extent of the SPA (distal to OKCL) were determined (Fig. 3). The average distance from the ulnar border of the ring finger and OKCL intersection to the SPA

Solid Arrow – distance between radial border ring finger and SPA

Dotted arrow – distance between ulnar border ring finger and SPA

Figure 3 Distances measured between OKCL at the radial and ulnar borders of the ring finger and the superficial palmar arterial arch. *Right*, ulnar border; *left*, radial border.

was 10.4 mm (range 6–18.2, SD 4.1). The average distance from the radial border of the ring finger and OKCL to the SPA was 11.8 mm (range 7.4–19.6, SD 4.3). Where incomplete arches were noted, the most radial extent of the SPA was utilized as a reference point. In all cases of incomplete arches, the most radial extent of the SPA was at least directly in line, distal to the intersection point of interest along the radial and ulnar borders of the ring finger.

Discussion

Relying on topographical landmarks as representations of underlying anatomical structures must be precise and reliable to ensure relative safe zones for surgical incisions. The pre-operative planning of incisions for both open and endoscopic CTR, in particular, the two portal Chow technique [3], represents a very common usage of one of these landmarks—Kaplan's cardinal line of the hand.

Other investigators, including Kaplan himself, have described numerous variations to the cardinal line [2, 10, 11, 19]. Current textbooks, even pinnacle works on surgical approaches, differ in their portrayal of KCL [7]. This ambiguity becomes important when one considers the complex neurovascular patterns in the volar hand [6, 8].

More importantly, since KCL has been described as representing the surface correlate of the motor branch of the median nerve [7, 19], deep branch of ulnar nerve [2, 9–11, 19], distal extent of the transverse carpal ligament [2], and the SPA [2, 9–11, 19], it becomes paramount to accurately define the landmark. Additionally, according to current surgical textbooks, KCL represents an accurate surface marker for the deep palmar arterial arch [7].

In our experience, the original description of KCL represents a surface marker for the clinical takeoff point of the SPA. The original description of KCL was chosen as opposed to subsequent variations based upon the clinical experience of the senior author (MAT). A survey of ASSH members published by Vella et al. in 2006 reinforces the widespread usage of the original description of KCL [26].

In performing both open and endoscopic CTR, the distal extent of an incision placed at the intersection of OKCL and the line along the long axis of the ring finger is a point past which iatrogenic injury to the SPA is possible [2, 9–11, 19]. Our results show an average distance of 10.2 mm from the distal extent of our incision to the SPA, theoretically allowing some inherent flexibility in planning of the incision for open and endoscopic CTR. However, due to the high level of variability of the SPA, we feel this flexibility is not realized [6, 8, 17, 22]. Previous investigations in volar hand arterial patterns have shown a complete SPA in only 60–86% of specimens [1, 5, 6, 8, 15, 17, 22]. Additionally, numerous anomalous patterns have

been identified—including a median artery in the midline of the palm—that can further complicate the utility of topographical markers of the hand [1, 22].

Several studies have examined the inter-relationships between anatomical surface markers and the SPA. Vasiliadis et al. looked at the distance between the distal portal of a Chow two-portal endoscopic CTR and the SPA [25]. Utilizing Kaplan's cardinal line and the axis of the third web space, the authors noted an average distance of 10.4 mm (range 5–15 mm). They noted the fat pad surrounding the SPA, just distal to the transverse carpal ligament, provides a useful adjunct in visualization for ligament release. Levy et al. performed a similar cadaveric study utilizing the original description of Chow's two portal technique [14]. They examined the wrists in both neutral position and in hyperextension, attempting to simulate the correct hand position during the procedure. They found an average distance of 13.7 mm (range 5–23) in neutral flex/ext and 17.4 mm (range 8–27) in hyperextension from the distal portal to the SPA.

Lee et al. also studied the anatomic inter-relationships during the two portal endoscopic CTR in cadaver specimens [12]. The authors made their distal portal incision as a transverse line 2.5–5 mm proximal to an intersection point of the proximal extension of the third web space and a line drawn ulnarly from a fully abducted thumb. This places the incision distal to OKCL. They noted an average distance of 4 mm between the distal portal incision and the SPA, with almost half of their specimens showing the incision to be at or proximal to the SPA. The clinical application of their incision would therefore be in danger of injuring the SPA.

Vella et al. examined in detail the utilization of KCL in 2005, reviewing relationships between all four known versions of KCL and underlying structures [26]. They noted the average distance between the OKCL and the SPA to be 14 ± 5 mm. Utilizing an alternate version—Kaplan's subsequent description in 1968 [11] as a line from apex of the interdigital fold between the index finger and thumb to a point 2 cm distal to the pisiform—they found an average distance of 11 ± 4 mm. While this line apparently is distal to the OKCL and still safely away from the SPA, clinically, we feel that its determination is somewhat unreliable. Previous trauma to the pisiform can alter its shape or location, and in obese individuals, palpation of the exact boundaries of the sesamoid bone can be difficult.

In addition to endoscopic CTR, a limited palmar incision approach has been investigated. This minimally invasive technique was founded on the principle of combining the safety and simplicity of formal open CTR with the reduced soft tissue trauma and post-operative morbidity seen in endoscopic CTR. Lee et al. examined the limited incision technique using OKCL as the distal extent of the incision in 28 cadavers and noted a complete ligamentous release in all

specimens [13]. Placement of the cutting tome in a distal to proximal direction at the distal aspect of the transverse carpal ligament was roughly 10 mm proximal to the SPA. They concluded that the safety of the vascular structures such as the SPA was never in jeopardy, thus supporting our study.

Iatrogenic injury to the SPA is not a benign occurrence. The overall incidence of iatrogenic injuries is less than 1.5% in open and endoscopic releases and less than 3.65% in limited incision procedures [15, 24]. Cases of aneurysmal dilation, post-operative hematoma leading to delayed healing, and ischemic symptomology have been reported.

Utilizing a one portal technique, Tsuruta et al. demonstrated difficulty in visualizing the SPA through the surrounding fat pad, rendering safe placement of instrumentation almost impossible [24]. The distance from the fat pad encompassing the SPA to the transverse carpal ligament has also been examined. Rotman and Manske dissected 28 cadaveric specimens and noted the fat pad to begin at least 8 mm proximal to the distal edge of the transverse carpal ligament [20]. Critical anatomical analysis of this finding points to the unreliability in utilizing the fat pad as a marker for limiting the distal extent of ligament release in order to spare the SPA.

The aforementioned fat pad becomes crucial in the two portal technique, as several authors have noted its utility in visualization of the SPA prior to ligament release via the distal portal [16, 23]. The variable distance from the distal edge of the transverse carpal ligament to the SPA echoes this observation.

Cobb et al. [4] and Omokawa et al. [17] have reported average distances of 12.5 mm (range 2–26) and 12 mm (range 4–18), respectively, from the distal extent of the transverse carpal ligament to the SPA. Rotman and Manske [20], however, reported distances substantially smaller, noting an average of 4.5 mm using the axis of the ring finger, with a range of 3–6 mm. This variability underscores the importance of utilizing a consistent surface marker to define the distal extent of an incision for CTR, such as the OKCL.

Even with training, complications and incomplete releases have been noted. Lee et al. [12] and Rowland and Kleinert [21] noted multiple complications and incomplete releases performed by fellowship and/or endoscopically trained hand surgeons. This highlights the high level of technical difficulty inherent to endoscopic CTR, and the clinical usefulness of a standard reference line such as the OKCL to plan one's CTR incisions.

There existed some limitations to the present study. First and foremost, this represents an anatomic study in nonliving tissue, and thus in vivo conditions could not be examined. We examined only the inter-relationship between the OKCL and the SPA, thus negating the effect of various

surrounding neurovascular structures on the feasibility of planned CTR incisions. It can be said, however, that our study focused entirely on the SPA and its vulnerability from proposed surgical incisions that utilize the KCL. Additionally, we noted a fairly substantial standard deviation of measurements from OKCL to the SPA. We speculated that the cadaveric post mortem processing might have altered the vascular relationships, leading to the sizable standard deviation. We do feel, however, that our sample of specimens reflects the broad spectrum of patient encountered in a hand surgery practice.

Based upon our results, we feel that the original description of KCL represents a consistent surface marker for a safe zone proximal to the SPA. The results of our anatomic study substantiate this concept, as there existed at least 6 mm of distance from the OKCL to the SPA, leaving ample space for dissection free from potential arterial compromise. Any CTR, whether via an open or endoscopic two portal method, should utilize this landmark as the distal most extent of a planned incision in order to minimize iatrogenic arterial injury and provide more consistent results.

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