**Objective:** This study aimed to determine the proper and safe needle insertion point in the flexor carpi radialis (FCR) muscle under ultrasonography guidance.

**Methods:** We identified the center point (CP) of the FCR as the optimal needle insertion point using ultrasonography. The location of the CP was analyzed using ratios and distances from other landmarks. The vertical distance (CP-VD) was measured by drawing an imaginary vertical line from the CP to the elbow crease. We measured the horizontal distance from the point where the imaginary vertical line from the CP meets the elbow crease to the biceps tendon at the elbow crease level (CP-HD). We presented the ratio of CP-HD to forearm circumference (HD ratio) and the ratio of CP-VD to forearm length (VD ratio) as percentages.

**Results:** The mean values of CP-HD and CP-VD were 2.0 ± 1.0 cm and 8.2 ± 1.1 cm, respectively. The mean HD and VD ratios were 8.4% ± 4.2% and 32.0% ± 3.1%, respectively.

**Conclusion:** When performing electromyography (EMG) of the FCR muscle, it is recommended to perform EMG at the point about 2 cm medial from the biceps tendon at the elbow crease level, to nearly the proximal one-third of forearm length.

**Keywords:** Flexor carpi radialis; Ultrasonography; Electromyography

**Introduction**

The flexor carpi radialis (FCR) muscle is the forearm superficial muscle originating in the medial epicondyle of humerus and inserted into the base of the 2nd and 3rd metacarpal bones. As the name suggests, the contraction of FCR muscle located on the surface of volar side of forearm causes flexion and radial deviation of the wrist [1].
The FCR muscle plays an important role in the evaluation and diagnosis of the C6 and C7 nerve root lesions or pathologic conditions associated with median nerve innervations, such as pronator teres (PT) syndrome, in electromyography (EMG) [2]. Also, FCR muscle is vulnerable to myofascial pain syndrome caused by repetitive movements such as wrist flexion/extension or ulnar/radial deviation [3]. Therefore, the FCR muscle is often targeted for trigger point injection. In addition, botulinum toxin is generally injected into the FCR muscle to manage spastic wrist flexors in patients with stroke or spinal cord injury, because FCR muscle is one of the muscles associated with forearm spastic postures under hypertonicity [4].

However, when botulinum toxin A injection was performed manually without instrumental guidance such as ultrasonography, the accuracy of needle entry into the FCR muscle was as low as 41.5% [5]. Also, it is difficult to penetrate the FCR muscle with a needle accurately along with serratus anterior, flexor carpi ulnaris (FCU), flexor pollicis longus, PT, and extensor indicis proprius muscles in the upper extremity [6].

Although the optimal needle insertion position for FCR muscle is clinically important, several needle EMG methods have been introduced [7-9]. In these studies, the needle insertion point was inaccurate using fingerbreadth, and the accuracy of needle insertion was not verified by ultrasonography. Also, the optimal needle insertion point varies with the patient demographic characteristics such as height. Song et al. [10] investigated the optimal area for FCR muscle injection in cadavers. However, the study had several limitations as living musculoskeletal structures differ from those of cadavers, and the sample size was small, which prevented discussion of proper depth of needle insertion. The aim of this study was to identify the center point (CP) of FCR muscle under ultrasonography guidance and to determine the most appropriate needle insertion point, considering the anatomical location.

Materials and Methods

1) Study design and participants

We enrolled 40 healthy subjects in this cross-sectional study. The study participants were prospectively recruited as volunteers. The sample size was calculated based on a previous study [10], which determined the anatomical localization of motor points of wrist flexors. In this previous study [10], the authors concluded that the motor point of FCR muscle was located at about proximal 27% of the FCR reference line connecting the medial epicondyle and the base of the 2nd metacarpal bone. Based on the primary outcome (p = 0.27), a power of 80% and a two-sided test (α = 0.05) and, a margin of error of 20%, we determined that the sample size required was 76. Assuming a 5% loss, we estimated that the final sample size required was 80, for a total of 40 participants for the study. Subjects older than 19 years were included. Exclusion criteria were (1) inability to cooperate with the examination due to systemic disease or mental illness, (2) upper extremity amputation, and (3) a cast, splint or metal that create artifact in forearm. Both forearms were examined in all participants, and a total of 80 forearms were enrolled. Demographic characteristics including age, sex, height, weight, body mass index (BMI), and forearm length affect the morphology of FCR muscle, and therefore were collected. Especially, we analyzed data focusing on height. Because tall people have long forearms [11], we thought that height was a major factor in determining the CP of the FCR muscle. In addition, since height can be estimated approximately, we thought it would be important during clinical examination. We defined forearm length as vertical distance from biceps tendon palpable at elbow crease to distal wrist crease, which is of sufficient consistency to be used as a reliable landmark [12]. The purpose and method of the study were explained to all subjects. All participants’ informed consent was obtained. The Institutional Review Board of Soonchunhyang University Bucheon Hospital approved this study (approval number: 2020-05-029-001).

2) Sonographic examinations

A single physiatrist conducted the ultrasonography evaluation for FCR muscle using a linear array transducer (7-18 MHz, Xario SSA-660A; Toshiba, Minato, Japan). Ultrasonographic evaluation was performed in supine position with the forearm fully supinated, and the shoulder abducted about 30°. We obtained all measurable data in this supine position.

Since the shape of FCR muscle is fusiform, we assumed that the CP of the FCR muscle was an optimal needle insertion point in this study. To determine the location of CP, we located the musculotendinous junction and the origin of FCR muscle using sonographic long and short-axis views. Musculotendinous junction and origin of FCR muscle were indicated on the skin, respectively. As shown in Fig. 1A, the vertical location of CP was in the midline between origin of FCR muscle and musculotendinous junction, which was an imaginary line parallel to the elbow crease. To verify the horizontal location of CP, the FCR muscle was examined by moving the ultrasound probe horizontally over this midline. As shown in Fig. 1B, we defined the point in short-axis sonographic image where FCR muscle was located at the center of sonographic image as CP. Drawing an imaginary vertical line from CP to elbow crease, the vertical distance (CP-
VD) was measured. The horizontal distance was measured from the point where the imaginary vertical line drawn from CP meets elbow crease to biceps tendon at the level of elbow crease (CP-HD) (Fig. 1A). Also, forearm circumference at CP was measured. Each person has distinct CP-HD and CP-VD due to their unique demographic characteristics. In order to suggest a representative value that is equally applicable to all people, we presented the ratio of CP-HD to forearm circumference (HD ratio) and ratio of CP-VD to forearm length (VD ratio) as a percentage.

The anatomical structures that could be penetrated by imaginary needle pathway were recorded on a short-axis sonographic image obtained in CP. If the median nerve was penetrated, the depth of the median nerve was recorded as a range from the depth of the most superficial part to the deepest part of the median nerve. The mid-depth (DM) was defined as the median value of DS and DD (Fig. 1B).

Needle insertion points were previously suggested via 3 needle EMG methods [7-9]. Preston and Shapiro [7] and Perotto and Delagi [9] suggested that the needle should be inserted at a distance of 4 fingerbreadths distal to the center of the wrist from the midpoint between the medial epicondyle and biceps tendon at elbow crease level (point A). Lee and DeLisa [8] suggested that the needle should be inserted at the proximal third of the imaginary line connecting the FCR tendon of the wrist and medial epicondyle (point B). Perotto and Delagi [9] recommended that the needle should be inserted at a distance of 4 fingerbreadths distal from the midpoint between the medial epicondyle and biceps tendon at elbow crease level (point C). These 3 needle EMG methods and CP were marked on the skin as shown in Supplementary Fig. 1. At each point, we acquired a cross-sec-
tional sonographic image and analyzed the anatomical structures that could be penetrated (Fig. 2). The depth of penetration was measured if the imaginary needle pathway penetrated the FCR muscle or median nerve. To ensure that the middle portion of
FCR was accurately penetrated by the imaginary needle pathway in each method, we defined the “middle portion” of the FCR muscle as the middle one-third when the muscle was divided into 3 segments in a horizontal axis. It was also recorded whether the middle portion of the FCR muscle was penetrated. In order to obtain accurate results, the ultrasound probe was carefully contacted with the skin with minimal pressure. The 4 fingerbreadths length of the physiatrist who conducted ultrasonography was about 7 cm.

3) Statistical analysis

Demographic characteristics and anatomical ultrasonography parameters are expressed as mean ± standard deviation, because the number of data (n = 80) was sufficient to ensure a normal distribution. Ultrasonography parameters (CP-HD, HD ratio, CP-VD, VD ratio, and DM) and demographic characteristics (height, weight, and BMI) were analyzed by correlation analysis. Sex differences were identified via Student t-test and Mann-Whitney was used for data that did not follow the normal distribution. Shapiro-Wilk test was performed to confirm normal distribution. A p-value of 0.05 or less was considered statistically significant. We used IBM SPSS Statistics ver. 26.0 (IBM Corp., Armonk, NY, USA) for all statistical analyzes.

Results

This study was performed on a total of 80 forearms involving 26 males and 14 females. The mean age was 31.4 ± 7.4 years; the mean height was 169.8 ± 9.5 cm; and the mean forearm length was 25.6 ± 2.0 cm. Other demographic data are summarized in Table 1.

Ultrasonography and anatomical parameters are presented in Table 2. The mean vertical distance from CP to elbow crease (CP-VD) was 8.2 ± 1.1 cm. The mean ratio of CP-VD to forearm length (VD ratio) was 32.0% ± 3.1%. The mean horizontal distance (CP-HD) was 2.0 ± 1.0 cm and the mean ratio of CP-HD to forearm circumference (HD ratio) was 8.4% ± 4.2%. The DS and DD of FCR muscle at CP were 3.7 ± 1.3 mm and 15.6 ± 2.2 mm, respectively. The DM of FCR muscle was 9.7 ± 1.3 mm (Table 2). Correlation analysis between ultrasonography parameters and demographic characteristics was performed (Table 3). CP-VD showed a significant positive correlation with height (R = 0.550, p < 0.01, Table 3). On the other hand, the VD ratio did not show a significant correlation with any demographic characteristics. Similarly, CP-HD and HD ratio did not show a significant correlation with any demographic characteristics. Among all variables, such as CP-HD, HD ratio, CP-VD, VD ratio, DD, DS and DM, only CP-HD, VD ratio and DM did not reveal significant differences between male and female (p-values 0.170, 0.052, and 0.947, respectively).

Table 4 demonstrates anatomical structures that could be penetrated by the imaginary needle pathway using each of the 4 different needle EMG methods [7-9]. Cross-sectional sonographic image of each point is presented in Fig. 1 and 2. The accuracy of penetration by the imaginary needle into FCR muscle was 82.5%, 20.0%, and 93.8% accuracy using methods A, B, and C, respectively. Methods A and C showed greater than 80% accuracy. However, the accuracy of penetration by the imaginary needle into the middle portion of FCR muscle was only 6.3%, 0%, and 38.8% in methods A, B, and C, respectively. Among the 3 methods, the probability of median nerve penetration was high in the order of A, C, and B (48.8%, 21.3%, 2.5%, respectively). Among the other structures, the PT, palmaris longus (PL) and flexor digitorum superficialis (FDS) muscles were also penetrated depending on the methods in question (Table 4). The median nerve penetration at CP was detected in 38 out of 80 (47.5%) forearms, showing a probability of 47.5%. In these 38 forearms, the mean
depth of the most superficial part of the median nerve was 18.61 mm and the mean depth of the deepest part was 21.31 mm.

### Discussion

In the present study, 80 forearms were analyzed to propose safe and proper needle placement of FCR muscle in 40 healthy participants. According to our study, CP-VD and CP-HD were found to be approximately 8.2 cm distal, and 2 cm medial from the palpable biceps tendon at the elbow crease level, respectively. However, the precise location of FCR muscle may vary since each person has a variable forearm length. Since we hypothesized that forearm length was proportional to height [11], the correlation analysis was performed. As a result, only CP-VD showed a significant positive correlation with height, implying that as the height increases, the forearm length is longer, and accordingly, the CP-VD increases. Thus, unlike CP-VD, the CP-HD can be used regardless of height. However, the VD ratio showed no significant correlation with height, weight, and BMI. Therefore, the VD ratio can be used as a vertical distance of FCR muscle, instead of CP-VD. Consequently, we conclude that the CP of FCR muscle is located approximately 2 cm medial from the biceps tendon at elbow crease level horizontally, and the proximal 32.0% of the forearm vertically regardless of height. Also, the average value DM of FCR muscle was 9.7 mm.

In a previous study, the biceps tendon and medial epicondyle were used as landmarks to localize the FCR muscle, suggesting that the FCR muscle might be located 4 fingerbreadths distal from the landmark (point A, C). Another study proposed the proximal third of imaginary line connecting the flexor carpi radialis tendon of the wrist and medial epicondyle [8]; method C, 4 fingerbreadths distal from the midpoint between the medial epicondyle and biceps tendon at the elbow crease level [9]; method CP, about 2 cm medial from the biceps tendon at the elbow crease level, to nearly the proximal one-third of forearm length.
that the needle insertion point was suggested based on the origin and insertion of the FCR muscle. In this method, they suggested that the needle should be inserted at the proximal third of the imaginary line connecting the FCR tendon of the wrist and medial epicondyle, considering forearm length. However, there was a problem that only the origin and insertion were considered and the accurate anatomy of the forearm flexors was not considered.

In the present study, we also used the biceps tendon, which is easily palpable at the elbow crease, as a landmark. However, we indicated the horizontal distance as a numerical value, and the vertical position as a proportional value based on ultrasonographic evaluation, which may be a more objective method than the other previous approaches, because our novel method did not use fingerbreadth that differs with each examiner. In addition, it considers variable heights for each examinee. VD ratio, which is approximately the proximal 1/3 of the forearm length, can be a good indicator for an intuitive approach. Additionally, the depth of FCR muscle, which was not mentioned in previous methods, was also suggested as 9.7 mm. Finally, these values did not show statistically significant differences according to sex as well as height.

As previously stated in the results, methods A and C had acceptable accuracy if used simply to penetrate FCR muscle. However, they were inaccurate if used to test or target the middle portion of FCR muscle (Table 4). Also, the accuracy of method B was substantially lower than that of methods A and C, given the anatomy of wrist flexor muscles. Wrist flexor muscles, such as FCU, PL, FCR, PT and FDS muscles, originate from medial epicondyle, considering forearm length. However, there was a problem that only the origin and insertion were considered and the accurate anatomy of the forearm flexors was not considered.

The study has several limitations. First, the mean age was 31.4 years old, and thus the study was targeted at relatively young people. Second, there might be slight difference between the suggested CP and the actual motor point of FCR muscle. We assumed that the actual motor point was close to the CP of the FCR muscle. Third, the average BMI of participants was 22.8 kg/m². The proper depth of needle insertion may differ in underweight or overweight and obese individuals. Fourth, we did not collect muscle mass data. Muscle mass measurement using dual energy X-ray absorptiometry is helpful in further studies. Fifth, in those without the PL muscle, the FCR belly is more likely to be located on the medial side. As mentioned earlier, this is because the FCR muscle is pushed laterally by FCU and PL muscles. Most standard textbooks of hand surgery report that the rate of absence of PL muscle was 15% [13-15]. Therefore, in such cases, it may be different from our findings. Sixth, we mea-
sured depth using ultrasonography without inserting the needle. However, when the needle is actually inserted, the shape of subcutaneous and muscle layers might be changed. Further studies involving more participants from variable age groups are required.

**Conclusion**

Several methods for proper needle placement have been suggested for FCR muscle. However, none of the methods have been evaluated in terms of safety and accuracy using ultrasonography. Accessing anatomical structures under ultrasonography guidance, we propose a novel method regardless of height. Also, we analyzed the accuracy of the previous methods and compared with our proposed strategy. These findings enable us to approach the CP of FCR muscle more accurately than previous methods. This study revealed that the CP of FCR muscle was approximately medial 2.0 cm from the biceps tendon at elbow crease, proximal one-third of forearm length, and at a depth of 9.7 mm. The method can be hopefully adopted more easily and safely in clinical applications.

**Conflict of Interest**

No potential conflict of interest relevant to this article was reported.

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**ORCID**

Jun Young Ahn, https://orcid.org/0000-0003-4340-2774
Sang-Hyun Kim, https://orcid.org/0000-0003-4475-5571
Seung Yeol Lee, https://orcid.org/0000-0003-1571-9408
Yeon Hae Cho, https://orcid.org/0000-0003-3009-395X
Back Min Oh, https://orcid.org/0000-0002-3219-0158
Hyun Seok, https://orcid.org/0000-0001-7266-6045

**Supplementary Materials**

Further details on supplementary materials are presented online (available at https://doi.org/10.18214/jend.2021.00017).

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