A Clinical Scoring System for Distinguishing Patients With Coincident Cubital Tunnel Syndrome Among Patients With Carpal Tunnel Syndrome

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Abstract

Background: Coincident carpal and cubital tunnel syndromes present a diagnostic challenge, exacerbated by the limitations of nerve conduction study (NCS) for confirming cubital tunnel syndrome. This study develops a diagnostic scoring system, the Koh-Benhaim (KB) score, to identify patients with coincident compression neuropathies. **Methods:** A retrospective review of 515 patients was performed from patients surgically treated for carpal and/or cubital tunnel release. These patients were divided as patients with isolated carpal tunnel syndrome ($n = 337$) or coincident carpal and cubital tunnel syndromes ($n = 178$), then characterized according to demographics, medical history, physical examination, and NCS results. Univariate and multivariate logistic regression identified predictors of coincident neuropathy. A clinical score was constructed by integerizing regression coefficients of predictive factors. Receiver operating characteristic (ROC) curves were generated for each iteration of the score. Sensitivities, specificities, and positive and negative predictive values were calculated to identify the best cutoff value. **Results:** Decreased intrinsic muscle strength, decreased ulnar sensation, positive elbow flexion test, positive cubital tunnel Tinel's sign, and abnormal NCS result were selected. The cutoff value for high risk of coincident compression was 3 points: positive predictive value, 82.9% and specificity, 93.4%. Model performance was very good—ROC area under the curve of 0.917. **Conclusions:** A KB score of 3 or greater represents high risk of coincident cubital tunnel compression. The variables involved are routinely used to assess the cubital tunnel, and all component factors of the KB score were of equivalent clinical weight in assessing patients with potential coincident compression neuropathy.

Keywords: coincident, carpal tunnel syndrome, cubital tunnel syndrome, nerve conduction study, score

Coincident carpal and cubital tunnel syndromes in patients presenting with symptoms of hand numbness, paresthesias, or weakness present a diagnostic challenge for clinicians. When assessing patients with suspected or proven carpal tunnel syndrome, provocative physical exam maneuvers and symptomatic presentation are the primary cues toward a diagnosis of simultaneous ulnar neuropathy at the elbow. In the most common current diagnostic paradigm, patients whose symptoms are suspicious for ulnar neuropathy are typically evaluated by nerve conduction study (NCS) with or without electromyogram to confirm the clinical diagnosis.^{1,3,7}

This diagnostic paradigm is limited, however, by the sensitivity of the NCS at the cubital tunnel. While NCS sensitivities at the carpal tunnel are generally cited at 90% to 95%, cubital tunnel NCS is significantly less sensitive—sensitivities are reported as low as 57%, with inconsistencies between retrospective studies. Without a reliable

confirmatory test, the decision-making process for patients who present with findings concerning for coincident compression neuropathy needs to be reevaluated.^{4,8,15}

Clinical scoring systems are widely applied in the practice of modern evidence-based internal medicine to guide decision making at diagnostic crossroads, particularly when a patient's management is considerably altered by the diagnosis that is ultimately made. In this case, assessing the presence of coincident cubital tunnel compression neuropathy in patients with carpal tunnel syndrome by using a clinical scoring system should be a logical evolution in these

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Figure 1. Study design schematic.

Note. CPT = current procedural terminology; H&P = history & physical.

patients' clinical assessment, particularly in the relative absence of a definitive confirmatory test.

Scoring systems such as the CHA₂DS₂-VASc test for assessing stroke risk in patients with atrial fibrillation, the CURB-65 score for determining the need for hospitalization of pneumonia patients, and the LRINEC (Laboratory Risk Indicator for Necrotizing Fasciitis) score for assessing necrotizing fasciitis are generally derived by analyzing the results of multivariate regression models, then identifying terms with the greatest diagnostic weight.^{2,5,6,9-11,14} We describe below a novel, simple, and effective scoring system, the Koh-Benham (KB) score, that uses routinely assessed physical exam findings and patient symptoms to distinguish patients with coincident compression neuropathy at the cubital and carpal tunnels from patients with isolated carpal tunnel syndrome.

Materials and Methods

Previously, this team reported an Institutional Review Board (IRB)-approved retrospective review of 515 patients, divided into cohorts of patients with isolated carpal tunnel syndrome

and patients with coincident carpal and cubital tunnel syndromes. Cohorts were assigned according to the final diagnosis reported in each patient's history and physical at their initial clinical presentation. The study population comprised only patients who demonstrated postoperative clinical improvement of their symptoms congruent with this initial diagnosis at follow-up encounters. Three hundred thirty-seven patients with isolated carpal tunnel syndrome were identified, undergoing 445 operations during this period. One hundred seventy-eight patients with coincident compression neuropathy were identified, undergoing 201 operations (Figure 1). These discrepancies in the number of patients versus the number of procedures were due to patients who required bilateral surgical intervention. One hundred sixteen patients were excluded for posttraumatic compressive symptoms following fractures, or postsurgical nerve compression symptoms associated with other wrist or elbow procedures, such as local tumor excision or prior nerve injury. These patients' charts were reviewed for demographic features, presenting symptoms, physical exam findings, and NCS results. The cohorts were then assessed by a multivariate logistic regression analysis to identify statistically significant factors as potential

targets for inclusion in a clinical scoring system that would more reliably predict the presence of coincident cubital and carpal tunnel syndromes.

Demographic parameters included age, gender, ethnicity, history of diabetes (and most recent HgA1c), history of tobacco use, history of upper extremity injury, and history of autoimmune disease. Patients' presenting symptoms included hand pain, numbness/paresthesias, fine motor deficits, prior general conservative treatment, history of wrist splinting, and history of triggering.

Physical exam findings specific for median neuropathy at the carpal tunnel included the Tinel's sign at the carpal tunnel, Phalen's test, median nerve compression test, decreased sensation within the median nerve distribution, thenar abduction strength test, and presence of thenar atrophy. Physical exam findings specific for the cubital tunnel included decrease in ulnar-innervated intrinsic muscle strength, ulnar-innervated intrinsic muscle atrophy, decreased sensation within the ulnar nerve distribution, elbow flexion test, Tinel's sign at the cubital tunnel, and Tinel's sign over the ulnar (Guyon's) tunnel.

The entire set was subject to a logistic multivariate regression analysis, to a confidence level of $P < .05$. Logistic multivariate regression was performed using the Stata statistical software package (StataCorp, College Station, Texas). Univariate logistic regression was performed for each of the statistically significant terms, and regression coefficients were also recorded. The developmental iterations of the KB score were constructed by converting the regression coefficients of statistically significant factors to integers.

Model calibration was then assessed by performing the Pearson chi-square goodness-of-fit test to each version of the score. The Pearson chi-square model was chosen because the number of covariate patterns was significantly less than the number of observations for each model. Predictive accuracy of each overall model was assessed as area under the curve (AUC) of the receiver operating characteristic (ROC) curve.¹² An AUC of 0.500 signifies a diagnostic test of no discriminatory value, unable to distinguish between true positive and true negative results, whereas an AUC of 1.000 would indicate a test with perfect diagnostic utility. The curve reflects the relationship between corresponding values of sensitivity and specificity at each possible cutoff to determine the model's effectiveness in distinguishing the 2 cohorts by predicting a diagnosis of coincident ulnar neuropathy at the cubital tunnel.

The developmental cohort was retrospectively scored by each iteration of the KB score, then reassessed for predictive accuracy, determined again by AUC of the ROC curve.

Results

In this developmental cohort, a summary of pertinent clinical characteristics is shown in Table 1.

Table 1. Summary of Clinical Features.

	Carpal tunnel	Carpal + cubital
Demographic features		
Average age (SD)	63.3 (15.1)	59.1 (16.2)
Male	32.9%	39.9%
Female	66.8%	60.1%
History of diabetes	18.6%	17.5%
HgA1c	5.8	5.9
History of tobacco use	12.2%	8.2%
History of UE injury	17.1%	22.8%
History of autoimmune disease	20.3%	25.0%
Symptoms		
Pain	22.0%	32.8%
Numbness/paresthesias	90.1%	94.0%
Fine motor deficits	48.5%	45.3%
Conservative treatment	40.6%	37.8%
Wrist splint	41.7%	39.3%
Triggering	16.1%	17.5%
Carpal tunnel exam		
Carpal tunnel Tinel's sign	70.2%	63.7%
Phalen's test	81.4%	70.2%
Median nerve compression test	85.2%	78.6%
Median distribution sensation loss	81.4%	65.2%
Thenar abduction test	44.4%	45.8%
Thenar atrophy	19.7%	14.9%
Cubital tunnel exam		
Elbow range of motion	7.9%	18.3%
Intrinsic strength loss	7.6%	54.7%
Intrinsic atrophy	1.1%	20.4%
Ulnar distribution sensation loss	6.7%	64.7%
Elbow flexion test	16.8%	66.2%
Cubital tunnel Tinel's sign	13.5%	70.7%
Ulnar tunnel Tinel's sign	6.7%	37.8%

Note. Statistically significant factors with shaded cells. SD = standard deviation; UE = upper extremity.

Four iterations of the KB scoring system were assessed. The first iteration ("KB-1," 10 terms) included all 10 statistically significant terms by multivariate regression: fine motor deficits, sensation loss within the median nerve distribution, median nerve NCS, patient-reported numbness, prior wrist splinting, loss of strength in ulnar nerve-innervated intrinsic muscles, sensation loss within the ulnar nerve distribution, elbow flexion test, cubital tunnel Tinel's sign, and ulnar nerve NCS (Table 2). Alternative simplified versions were also generated—first by removing the negatively predictive score components ("KB-2," 7 terms), then by limiting the score to physician exam findings ("KB-3," 5 terms). An alternative 5-component score was also generated by using the statistically significant regression coefficients from the univariate analysis, disregarding terms with significantly lower

Table 2. Summary of Multivariate Logistic Regression Results.

	OR	Coefficient	95% CI
Age, >50	0.55	-0.60	0.26-1.14
Pain	1.70	0.53	0.88-3.30
Subjective numbness	19.51	2.98	4.44-85.65
Fine motor deficits (carpal tunnel)	0.43	-0.87	0.23-0.80
Conservative therapy	0.46	0.77	0.20-1.05
History of splinting	2.31	0.85	0.99-5.39
Triggering	1.04	0.00	0.48-2.24
Intrinsic strength loss	3.30	1.19	1.644-6.61
Intrinsic atrophy	2.51	0.92	0.65-9.72
Ulnar nerve sensation loss	8.82	2.17	4.61-16.84
Elbow flexion test	4.36	1.50	2.18-8.69
Cubital Tinel's sign	2.98	1.07	1.50-5.95
Ulnar Tinel's sign	1.62	0.48	0.75-3.51
Carpal Tinel's sign	0.68	-0.38	0.34-1.35
Phalen's test	0.57	-0.55	0.25-1.30
Median nerve compression test	0.95	-0.10	0.36-2.50
Median nerve sensation loss	0.39	-0.93	0.19-0.78
Thenar abduction strength	1.79	0.58	0.94-3.41
Thenar atrophy	0.99	-0.01	0.43-2.28
Ulnar NCS	9.85	2.33	4.85-19.99
Median NCS	0.40	-0.92	0.20-0.81

Note. Statistically significant factors with shaded cells. OR = odds ratio; CI = confidence interval; NCS = nerve conduction study.

Table 3. Statistically Significant Univariate Regression Components and KB-4 Derivation.

	Univariate regression coefficient	Integerized
Subjective numbness	0.5	—
Intrinsic muscle strength	2.7	1
Ulnar sensation loss	3.2	1
Elbow flexion test	2.3	1
Cubital tunnel Tinel's sign	2.7	1
Ulnar NCS	2.6	1

Note. NCS = nerve conduction study.

regression coefficients ("KB-4," Table 3). All iterations are summarized in Table 4, indicating the relative score weights of each component for each iteration of the KB score.

The 10-component model used by the KB-1 score showed an ROC AUC of 0.9453. (Figure 2) This model had a sensitivity of 77.6%, and specificity of 93.7%. The positive predictive value (PPV) was 84.8%, and the negative predictive value was 90.3%. The Pearson chi-square statistic was not appropriate for this particular model, as it included values with negative regression coefficients. Possible score values ranged from -6 to 24. The weighted KB-1 score showed an ROC AUC of 0.9391.

Table 4. KB Score Iterations and Component Point Weights.

Parameter	KB-1	KB-2	KB-3	KB-4
Fine motor deficits	-2	—	—	—
Median sensation loss	-2	—	—	—
Median NCS	-2	—	—	—
Numbness	6	6	—	—
Prior wrist splint	2	2	—	—
Intrinsic strength loss	2	2	2	1
Ulnar sensation loss	4	4	4	1
Elbow flexion test	3	3	3	1
Cubital tunnel Tinel's sign	2	2	2	1
Ulnar NCS	5	5	5	1
Total possible	-6 to 24	0-24	0-16	0-5

Note. KB = Koh-Benham; NCS = nerve conduction study.

A

B

Figure 2. A, Ten-component model ROC curve. B, Score-weighted 10-component model ROC curve (KB-1).

Note. ROC = receiver operating characteristic.

The 7-component model used by the KB-2 showed an ROC AUC of 0.9312. (Figure 3) The Pearson chi-square statistic was calculated at 0.4369, with a sensitivity of

Figure 3. A, Seven-component model ROC curve. B, Score-weighted 7-component model ROC curve (KB-2).
Note. ROC = receiver operating characteristic.

80.6%, and specificity of 91.0%. PPV was 80.2%, and negative predictive value was 91.2%. Possible score values ranged from 0 to 24. The weighted KB-2 score showed an ROC AUC of 0.9277.

The 5-component model used by the KB-3 and KB-4 showed an ROC AUC of 0.9295. (Figure 4) The Pearson chi-square statistic was calculated at 0.1352, with a sensitivity of 82.1%, and specificity of 90.1%. The PPV was 79.0%, and the negative predictive value was 91.8%. Positive KB-3 score values ranged from 0 to 16. The weighted KB-3 score showed an ROC AUC of 0.929. Possible KB-4 score values ranged from 0 to 5. The univariate regression coefficients for the weighted KB-4 showed an ROC AUC of 0.9217.

Using each of the potential scoring systems, all possible values were tested as cutoff thresholds—Sensitivities, specificities, PPVs, and negative predictive values were calculated for each possible cutoff score. Score values were then stratified into categories by PPV, indicating low (<65%),

Figure 4. A, Five-component model ROC curve. B, Score-weighted 5-component model ROC curve (KB-3). C, Score-weighted univariate 5-component model ROC curve (KB-4).
Note. ROC = receiver operating characteristic.

moderate (65%-75%), high (75%-90%), and very high (>90%) PPV risk of coincident carpal and cubital tunnel compression neuropathies. Table 5 lists the score ranges corresponding to each of these stratified risk categories.

Table 5. Cutoff Values for KB Iterations.

Risk cutoffs	KB-1	KB-2	KB-3	KB-4
Low	-6 to 6	0-9	0-3	0-1
Moderate risk	7	10-11	4-5	2
High risk	8-13	12-18	6-9	3
Very high risk	14-26	19-26	10-16	4-5

Note. KB = Koh-Benham.

Among the 4 iterations of the KB score, the 10-term KB-1 demonstrated the highest ROC AUC, with the greatest specificity (0.908) and PPV (0.802). The 5-term KB-4 demonstrated the greatest sensitivity (0.866) and negative predictive value (0.934). All 4 iterations of the KB score demonstrated excellent diagnostic performance for coincident cubital tunnel syndrome in patients with carpal tunnel syndrome, with ROC AUCs greater than 0.9. The most complex and inclusive iteration, KB-1, did perform slightly better than the others, but even the KB-4, the simplest iteration, maintained strong discriminatory power.

Discussion

Each iteration of the KB score is capable of effectively detecting coincident compression neuropathy during a patient's initial evaluation and presentation among patients with isolated carpal tunnel syndrome. In terms of model performance, the KB-2 (10-component model) score had the best performance by ROC AUC. As additional terms were removed to simplify the complexity of scoring protocols, the AUC decreased, but even the most simplified 5-component model showed an ROC AUC of 0.9295, indicating excellent performance. In addition, the 7- and 5-component tests without negatively correlated terms showed Pearson chi-square of 0.4369 and 0.1352, respectively, indicating that the models had good fit in this developmental study population, able to effectively distinguish the 2 cohorts.

Successful and clinically relevant scores should not only reflect optimal modeling and easy distinction between risk-stratified groups but also be easy for clinicians to use and remember. Although complex scoring systems are routinely evaluated using smartphone medical calculator apps, we propose that the simplest and easiest-to-remember model that retains good model performance should be utilized in clinical practice. Therefore, given excellent model performance with a simple 5-point, equally weighted scoring system (formerly KB-1), we propose the introduction of the KB score based on the presence of intrinsic strength loss, sensation loss in the ulnar nerve distribution, positive elbow flexion test, positive cubital tunnel Tinel's sign, and positive ulnar nerve NCS. Based on this developmental cohort, we propose a score threshold of 2 points as the cutoff for

assessing patients with moderate risk, 3 points for high risk, and 4 points for very high risk of coincident cubital tunnel syndrome in patients with carpal tunnel compression neuropathy. In this cohort, only 1.8% of patients with isolated carpal tunnel syndrome showed a score of 4 or greater, decreasing to 0.4% for a score of 5 points.

A KB moderate risk score threshold of 2 points carries important implications for clinical diagnosis of coincident cubital tunnel syndrome in patients with carpal tunnel syndrome. With equivalent diagnostic weight for all 5 score components, the current diagnostic paradigm of confirmation by NCS is called into question. A patient with a negative NCS result at the cubital tunnel can still reach a KB score of 4 for very high risk of coincident compression neuropathy; 62.4% of patients with KB scores of 4 or 5 would still score 4 points without an NCS result. For the moderate risk threshold, 93.6% of patients with KB scores of 2 or higher would still reach this threshold without an NCS result. A minimum threshold of 2 points also prevents the test from being excessively sensitive. For example, given differences in physician physical exams, it is well known that the Tinel's sign at the cubital tunnel can be elicited in an otherwise asymptomatic patient with either a highly sensitive patient or an overly enthusiastic examiner.

In addition to further validation studies, the score can also potentially be modified with other strongly predictive factors for identifying patients with multiple compression neuropathies. In this study, physical exam findings and symptomatic presentations that were not consistently evaluated in the full cohort could not be evaluated. For example, the scratch collapse test is a somewhat controversial provocative test for evaluation of compression neuropathy in the upper extremity that was first reported in 2008, with sensitivities significantly outperforming the classical battery of provocative testing.¹³ In this cohort, only 19% of the study population had been evaluated by the scratch collapse test, making its inclusion in the multivariate regression inappropriate.

The database and patient populations used to derive the score were originally designed to identify risk factors and physical exam findings that would predict coincident compression neuropathy. During the course of this analysis, however, the limitations of current diagnostic paradigms for cubital tunnel syndrome became clear, particularly with regard to the role of electrodiagnostics. The authors recognized an opportunity to use this retrospective database as a starting point for clarifying this diagnostic landscape with evidence-based, statistically driven methods. In particular, the profiles of patients diagnosed with isolated carpal tunnel syndrome presented a very natural control group. Based on the encouraging strong performance of the KB scoring paradigm, the authors hope that these results can be the foundation for future prospective studies with appropriately designed validation cohorts. In this developmental cohort,

the score was a robust, simple, and straightforward index for efficiently stratifying patient risk of symptomatic coincident carpal/cubital compression neuropathy.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

Additional informed consent was obtained from all individual participants for whom identifying information is included in this article.

Declaration of Conflicting Interests

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