OPEN Research Article

Association of Clinical Findings With Complications in the Cubitus Varus Deformity After Supracondylar Fracture

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ABSTRACT

Introduction: Cubitus varus deformity is primarily a cosmetic complaint that causes some early and late complications. However, no studies have reported the cubitus varus deformity regarding the frequency of complications, relationship to the degree of deformity, and period from the occurrence of the initial injury.

Methods: Overall, 83 patients with cubitus varus deformity were examined. The differences in the humerus-elbow-wrist angle (ΔHEW-A), tilting angle (ΔTA), and internal rotation angle (ΔIRA) between the affected and normal sides were measured to determine varus and extension and internal rotation deformity. The period from the occurrence of the initial injury to the evaluation date was also investigated. Multivariate logistic regression analysis was conducted to identify the explanatory variables (period, ΔHEW-A, ΔTA, and ΔIRA) independently associated with complication events. Receiver-operating characteristic curve analysis was also conducted to predict the risk of events.

Results: ΔHEW-A was independently associated with the risk of cosmetic complaint (odds ratio [OR], 1.171; 95% confidence interval [95% CI], 1.056 to 1.336) and instability (OR, 1.111; 95% CI, 1.028 to 1.200). ΔTA was independently associated with the risk of limited elbow motion (OR, 1.176; 95% CI, 1.077 to 1.285) and sports disability (OR, 0.892; 95% CI, 0.836 to 0.952). The period from the occurrence of the initial injury was independently associated with risk of pain (OR, 1.063; 95% CI, 1.019 to 1.108), ulnar nerve neuropathy (OR, 1.065; 95% CI, 1.011 to 1.125), and osteoarthritis (OR, 1.188; 95% CI, 1.098 to 1.286). The receiver-operating characteristic curve analysis revealed the optimal cutoffs of 20° and 27° for ΔHEW-A to predict cosmetic complaint and instability; of 25° for ΔTA to predict limited elbow motion; and of 8.8, 8.0, and 16.0 years for the period to predict pain, ulnar nerve neuropathy, and osteoarthritis, respectively.

Discussion: The treatment of cubitus varus deformity should be determined because a residual deformity >20° of varus and 25° of extension could develop risk of complications over time.

Supracondylar fractures of the distal humerus are common injuries of the elbow in children. Conservative treatment with cast immobilization in cases of incomplete reduction often leads to malunion. Cubitus varus deformity is the most common deformity resulting from supracondylar fractures.[1-3] Cubitus varus deformity causes not only cosmetic problems but some early and late complications. Varus deformity increases the risk of secondary lateral condylar fractures of the distal humerus,[4,5] and extension deformity causes the restriction of elbow flexion. Lateral instability caused by the dysfunction of the lateral ulnar collateral ligament (LUCL) leads to posterolateral rotatory instability of the elbow.[6-8] Tardy ulnar palsy[9-11] and osteoarthritis (OA)[12,13] caused by the alignment change in the elbow develop sometimes in chronic cases. However, no studies have reported the detailed association of clinical findings with complications in the cubitus varus deformity after supracondylar fracture, including the frequency of complications, relationship to the degree of deformity, and period from the occurrence of the initial injury. Therefore, in the early period, the indication for corrective surgery for cubitus varus deformity is often based on the patient's cosmetic complaints. Although corrective surgery is performed in cases with limited elbow range of motion (ROM) or in cases with moderate-to-severe deformity that is expected to lead to future complications, there are currently no established criteria for the deformity angle, indicating the need for corrective osteotomy to prevent these complications.[14-17] Thus, this study aimed to retrospectively investigate the incidence of complications associated with cubitus varus deformity and identify predictors for these complications.

Methods

Ethical Approval

This retrospective study was approved by the institutional review board of Osaka University Hospital, Suita, Japan, and followed the tenets of the Declaration of Helsinki as revised in 2000. Each author certifies that his or her institution approved the human protocol for this investigation, all investigations were conducted in conformity with the ethical principles of research, and informed consent was obtained from all study participants.

Participants

Data of patients with cubitus varus deformity after supracondylar fractures who underwent corrective osteotomies at our institution between June 2002 and June 2022 were retrospectively reviewed. Three-dimensional corrective osteotomies using patient-matched surgical guides that were created based on preoperative simulation were used to access functional disabilities of the elbow and/or cosmetic concerns related to cubitus varus deformity that concerned the patient.[18] Patients with unilateral cubitus varus deformity treated with corrective osteotomy because of the abovementioned symptoms were included. Patients with congenital deformity and those with histories of fractures, except supracondylar fractures, were excluded. In total, 83 patients were included in this study. The median age of the participants was 12.0 (9.0 to 18.0) years at the time of surgery, and there were 18 female and 65 male participants.

Data Collection

Data of all symptoms related to cubitus varus deformity were collected from the medical records of the patients. The symptoms included cosmetic complaints, restriction of flexion and extension ROM, elbow instability, pain, and ulnar nerve neuropathy. The period from the occurrence of the initial injury to the date of corrective osteotomy; history of secondary lateral condylar fractures of the humerus, which is one of the complications of cubitus varus deformity; and poor performance in sports activities were also investigated. Because the exact onset time of complication events was unknown, the period related to events was defined from the occurrence of the initial injury to the date of corrective osteotomy for convenience.

Measurements

All patients were radiographically and physically evaluated before the operation. The humerus-elbow-wrist angle (HEW-A) on the anterior-posterior radiograph and tilting angle (TA) on the lateral radiograph were measured on the affected and normal sides, and the differences in measurements between both sides were defined as deformities on the coronal (ΔHEW-A) and sagittal (ΔTA) planes.[19,20] The internal rotation angle (IRA) of the shoulder on both sides was physically measured according to the method described by Yamamoto et al,[21] and rotational deformity was defined as hyper-internal

rotation of the shoulder (ΔIRA), which indicates the difference in IRA between the affected and normal sides (Figure 1, A–C). Positive ΔHEW-A, ΔTA, and ΔIRA values indicated varus and extensional and internal rotation deformities, respectively. The presence of elbow OA was assessed on anterior-posterior and lateral plain radiographs, and its severity was categorized according to the Kellgren-Lawrence grading system as follows: normal, grade 0; very mild, grade 1; mild, grade 2; moderate, grade 3; and severe, grade 4.[22] Patients were physically assessed for bilateral elbow ROM using a goniometer. Elbow instability was graded as follows: grade 0, no instability; grade 1, mild laxity with a good end point; grade 2, moderate laxity with no end point; and grade 3, gross instability.[23] Ulnar nerve neuropathy was diagnosed based on the presence of numbness and/or sensory loss in the ring and little fingers and a conduction velocity of <45 m/s across the elbow.

Statistical Analysis

All statistical analyses were conducted using JMP Pro 14 (SAS, Cary, NC). Data were assessed for normal distribution using the Shapiro-Wilk test. Data were presented as mean ± standard deviation or median [interquartile range]. Significance was established at $P < 0.05$. This study was designed as a hypothesis-generating exploratory study; therefore, no adjustment for multiplicity was made.

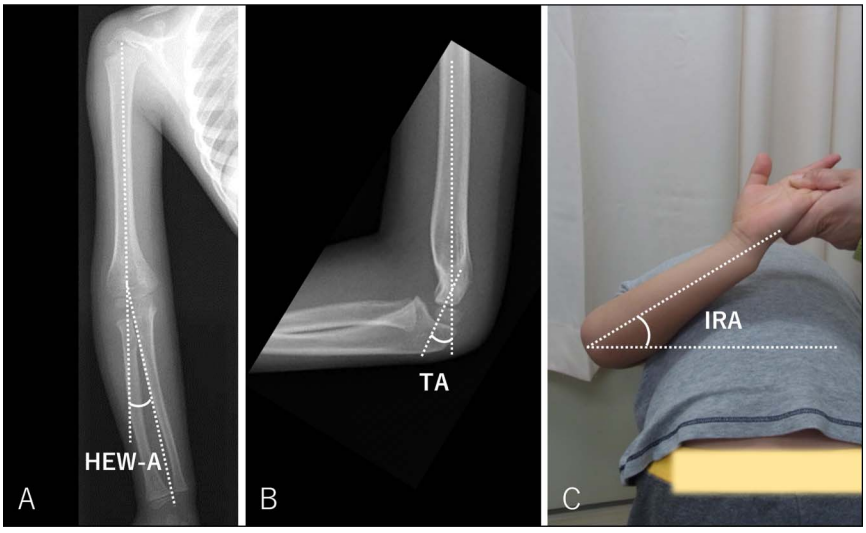
Multivariate logistic regression analysis was conducted to identify the explanatory variables independently associated with the complication events. The explanatory variables were the period from the occurrence of injury to the date of corrective osteotomy and deformity parameters (ΔHEW-A, ΔTA, and ΔIRA), all of which were entered into the multivariable analysis. The analysis was independently conducted for each of the eight event complications, namely, limited elbow ROM, cosmetic complaints, lateral condylar fractures, instability, sports disability, pain, ulnar nerve neuropathy, and OA.

Receiver-operating characteristic curve analysis was also conducted to predict the risk of events using the variables in each event that presented notable differences in the multivariate logistic regression analysis. The area under the curve (AUC) was calculated, and the cutoff values to predict the risk of events were determined using the Youden index. The accuracy of the AUC was classified as low (AUC = 0.5 to 0.7), moderate (AUC = 0.7 to 0.9), or high (AUC = 0.9 to 1.0).

Results

Demographic and clinical details of the patients are summarized in Table 1. The median period from the occurrence of the initial injury was 6.3 [3.0 to 14.8] years. The ΔHEW-A, ΔTA, and ΔIRA were 26.4° ± 8.2°, 16.2° ± 9.7°, and 12.1° ± 11.5°, respectively. The most common event was cosmetic complaints that were noted in 75 cases (90.4%), followed by sports disability in 30 (36.1%), pain in 23 (27.7%), limited elbow ROM in 20 (24.1%), instability in 20 (24.1%; grade 1, n = 9; grade 2, n = 5; and grade 3, n = 6), history of secondary

Figure 1



Radiographs and image demonstrating measurement methods of humerus-elbow-wrist angle (HEW-A) on anterior-posterior plain radiograph (**A**), tilting angle (TA) on lateral plain radiograph (**B**), and internal rotation angle (IRA) by physical examination (**C**).

Table 1. Patients' Demographic and Clinical Details

Patients' demographic data	
Number	83
Age at evaluation (y)	12.0 [9.0-18.0]
Age at initial injury	5.0 [3.8-7.0]
Male:Female, n	65:18
Affected side, n (Right:Left)	37:46
Period from the initial injury (y)	6.3 [3.0-14.8]
Flexion ROM (°)	130.0 [120.0-140.0]
Extension ROM (°)	15.0 [5.0-20.0]
ΔHEW-A (°)	26.4 ± 8.2
ΔTA (°)	16.2 ± 9.7
ΔIRA (°)	12.1 ± 11.5
Event	
Cosmetic complaint, n (%)	75 (90.4%)
Sports disability, n (%)	30 (36.1%)
Pain, n (%)	23 (27.7%)
Limited elbow ROM, n (%)	20 (24.1%)
Instability, n (%, grade 1:2:3)	20 (24.1%, 9:5:6)
Lateral condyle fracture, n (%)	17 (20.5%)
OA, n (%, grade 1:2:3:4)	15 (18.1%, 10:3:2:0)
Ulnar nerve neuropathy, n (%)	8 (9.6%)

ΔHEW-A = Δhumerus-elbow-wrist angle, ΔTA = Δtilting angle, ΔIRA = Δinternal rotation angle, OA = osteoarthritis, ROM = range of motion
Data are presented as mean ± standard deviation or median (interquartile range).

lateral condylar fractures in 17 (20.5%), OA of the elbow in 15 (18.1%; grade 1, n = 10; grade 2, n = 3; grade 3, n = 2; grade 4, n = 0), and ulnar nerve neuropathy in 8 (9.6%). Of the 30 patients with sports disabilities, 16 were in ball sports, four in gymnastics, three in swimming, three in weight training, two in track and field, and two in martial arts.

The period from the occurrence of the initial injury for each event was in ascending order, as follows: 2.4 [1.1 to 6.0] years for limited elbow ROM; 6.0 [3.0 to 14.0] years, cosmetic complaints; 6.0 [4.8 to 12.0] years, history of secondary lateral condylar fractures; 8.5 [3.0 to 14.0] years, instability; 9.0 [5.8 to 16.5] years, sports disability; 14.0 [6.3 to 34.0] years, pain; 25.0 [11.5 to 32.8] years, ulnar nerve neuropathy; and 34.4 [25.0 to 42.0] years, OA. The multivariate odds ratios (ORs) and 95% confidence intervals (CIs) of each event are provided in Table 2 and Figure 2.

Collectively, the ΔHEW-A was independently associated with the risk of cosmetic complaints (OR, 1.171; 95% CI, 1.056 to 1.336) and instability (OR, 1.111; 95% CI, 1.028 to 1.200). The ΔTA was independently associated with the risk of limited elbow motion (OR, 1.176; 95% CI, 1.077 to 1.285) and sports disability (OR, 0.892; 95% CI, 0.836 to 0.952). The period from the occurrence of the initial injury was independently associated with the risk of pain (OR, 1.063; 95% CI, 1.019 to 1.108), ulnar nerve neuropathy (OR, 1.065; 95% CI, 1.011 to 1.125), and OA (OR, 1.188; 95% CI, 1.098 to 1.286).

The receiver-operating characteristic curve analysis revealed the optimal cutoffs of 20° (AUC = 0.78, moderate) and 27° (AUC = 0.67, low) for ΔHEW-A to predict cosmetic complaints and instability and of 25° (AUC = 0.83, moderate) and 15° (AUC = 0.75, moderate) for ΔTA to predict limited elbow motion and sports disability, respectively. Moreover, the cutoff values of 8.8 years (AUC = 0.74, moderate), 8.0 years (AUC = 0.84, moderate), and 16.0 years (AUC = 0.92, high) indicated the periods from the occurrence of the initial injury to predict pain, ulnar nerve neuropathy, and OA, respectively (Figure 3, A–G).

Table 2. Multivariate-Adjusted Odds Ratios for the Occurrence of Each Event

Event (Overall *P*)	Variable	Yes	No	*P*
Limited elbow ROM ($P < 0.001$)	Number	20	63	
	Period (y)	2.4 [1.1-6.0]	8.0 [5.0-18.0]	0.058
	ΔHEW-A (°)	26.4 ± 8.6	26.4 ± 8.2	0.933
	ΔTA (°)[a]	24.9 ± 8.8	13.2 ± 8.4	<0.001
	ΔIRA (°)	12.8 ± 10.9	11.9 ± 11.8	0.536
Cosmetic complaint ($P = 0.023$)	Number	75	8	
	Period (y)	6.0 [3.0-14.0]	12.0 [2.8-33.1]	0.100
	ΔHEW-A (°)[b]	27.2 ± 7.8	18.6 ± 8.1	0.007
	ΔTA (°)	15.9 ± 9.0	16.8 ± 16.4	0.264
	ΔIRA (°)	12.0 [4.0-18.0]	9.0 [1.0-19.0]	0.940
Lateral condyle fracture ($P = 0.291$)	Number	16	67	
	Period (y)	6.0 [4.8-12.0]	7.0 [2.4-15.2]	0.678
	ΔHEW-A (°)	29.3 ± 9.6	25.7 ± 7.7	0.077
	ΔTA (°)	17.2 ± 6.3	15.9 ± 10.5	0.876
	ΔIRA (°)	4.1 ± 11.6	8.7 ± 15.5	0.172
Instability ($P = 0.006$)	Number	20	63	
	Period (y)	8.5 [7.2-28.0]	6.0 [2.2-12.0]	0.282
	ΔHEW-A (°)[b]	30.0 ± 9.5	25.3 ± 7.5	0.008
	ΔTA (°)	16.5 [8.5-20.0]	15.0 [10.0-25.0]	0.063
	ΔIRA (°)	9.4 ± 8.1	13.0 ± 12.3	0.080
Sports disability ($P = 0.001$)	Number	30	53	
	Period (y)	9.0 [5.8-16.5]	6.0 [2.0-11.0]	0.909
	ΔHEW-A (°)	25.4 ± 8.1	27.0 ± 8.3	0.707
	ΔTA (°)[d]	10.5 ± 9.1	19.2 ± 8.8	<0.001
	ΔIRA (°)	10.0 [1.5-19.3]	13.0 [5.0-18.0]	0.449
Pain ($P = 0.002$)	Number	23	60	
	Period (y)[c]	14.0 [6.3-34.0]	6.0 [2.3-8.8]	0.004
	ΔHEW-A (°)	28.2 ± 9.4	25.7 ± 7.7	0.094
	ΔTA (°)	13.6 ± 10.4	17.0 ± 9.5	0.321
	ΔIRA (°)	7.0 [0.0-16.0]	13.0 [6.0-19.0]	0.077
Ulnar nerve neuropathy ($P = 0.112$)	Number	8	75	
	Period (y)[c]	25.0 [11.5-32.8]	6.0 [2.7-11.0]	0.018
	ΔHEW-A (°)	26.4 ± 7.3	26.4 ± 8.4	0.986
	ΔTA (°)	11.5 ± 6.3	16.5 ± 10.0	0.407
	ΔIRA (°)	11.0 [8.0-19.0]	11.0 [3.0-18.0]	0.479

(*continued*)

Table 2. (*continued*)

Event (Overall *P*)	Variable	Yes	No	*P*
OA ($P < 0.001$)	Number	15	68	
	Period (y)[c]	34.4 [25.0-42.0]	6.0 [2.5-8.0]	<0.001
	ΔHEW-A (°)	27.1 ± 8.9	26.3 ± 8.1	0.536
	ΔTA (°)	14.7 ± 9.7	16.5 ± 9.8	0.594
	ΔIRA (°)	10.0 [8.0-16.0]	12.0 [4.0-18.8]	0.301

ΔHEW-A = Δhumerus-elbow-wrist angle, ΔTA = Δtilting angle, ΔIRA = Δinternal rotation angle, OA = osteoarthritis, ROM = range of motion
Data are presented as mean ± standard deviation or median (interquartile range).
[a]Indicates that ΔTA is significantly greater for the group with a complication than for that without a complication.
[b]Indicates that ΔHEW-A is significantly greater for the group with a complication than for that without a complication.
[c]Indicates that period from injury is significantly longer for the group with a complication than for that without a complication.
[d]Indicates that ΔTA is significantly smaller for the group with a complication than for that without a complication.

Discussion

Cubitus varus deformity is a three-dimensional deformity that includes extension and internal rotation in addition to varus deformity.[24-27] Although the distal humerus has potential of remodeling extension deformity along the sagittal plane until the age of 10, varus and internal rotation deformities remain because of the poor remodeling capability on the coronal and axial planes.[3,19,28-30] As previously reported, residual deformities cause early complications including limited elbow flexion, cosmetic complaints, and lateral humeral condylar fractures[4,5]; midterm complications including elbow instability[6-8]; and late complications including elbow pain, ulnar neuropathy,[9-11] and OA.[12,13] Some patients also have limited involvement in sports that require high demands for upper extremity function.

In this study, 90.4% of the patients who underwent corrective osteotomy cared about the unsightly physical appearance of the elbow, and the cosmetic problem is a major complication of cubitus varus deformity. When the varus deformity angle exceeds the cutoff value of 20° compared with the normal side, it could have latent psychological effects on the patient. Although orthopaedic surgeons tend to focus on physical functions, treatment should also consider the concerns of patients about the appearance of the elbow deformity.

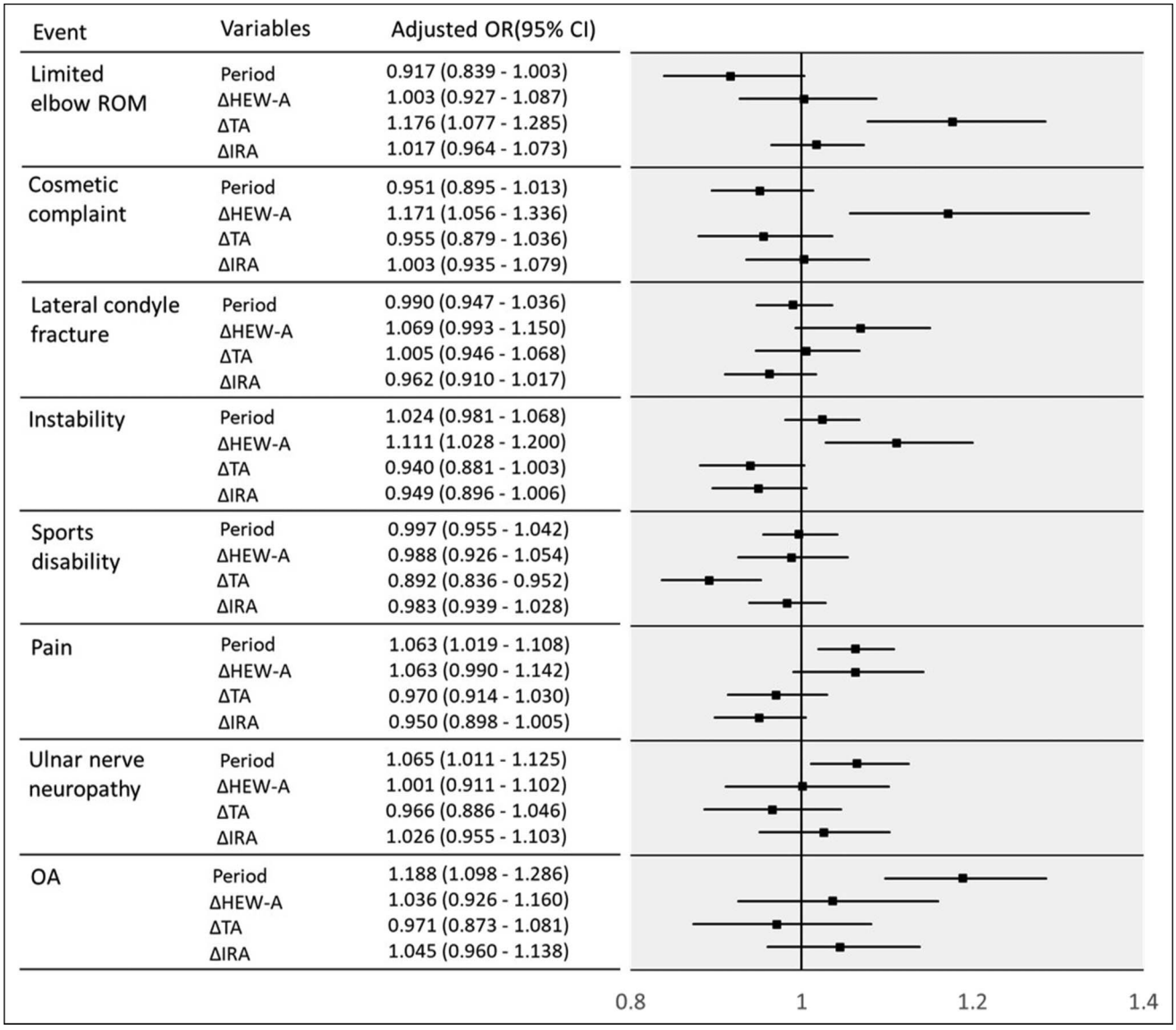
In cubitus varus, the mechanical axis of the upper extremity is shifted medially, causing strain stress on the lateral side of the elbow when loading with the upper limb. The LUCL is subjected to chronic strain stress, which leads to elbow instability. The cutoff value of 27° for the ΔHEW-A to predict elbow instability aligned with the result of a previous cadaveric study.[6] This study reported that the widening of the ulnohumeral joint space was markedly increased at 25° of relative varus deformity, and the LUCL strain was markedly increased at 30° of relative varus deformity.[6] If varus deformity exceeds the ΔHEWA of 27°, the chances of unstable elbow will likely be higher, which indicates that correction surgeries are required before elbow instability develops.

The decrease in the anterior tilt of the condyles because of the extension deformity of the distal humerus reduces the offset of the elbow flexion axis from the humerus longitudinal axis; consequently, the flexion limitation angle may appear larger than the angle of extension deformity because the space for the soft tissue at the elbow flexion is small.[31,32] This indicated that the influence of the extension deformity angle on elbow flexion limitation is often underestimated. Moreover, the result of this study reveals that the ΔTA cutoff value of 25° of extension deformity could be an index value of image evaluation for elbow motion limitation.

The cutoff values of the period for elbow pain, ulnar neuropathy, and elbow OA were 8.8, 8.0, and 16 years, respectively, and cubitus varus deformity should be treated with consideration of late complications.

To our knowledge, no study has focused on sports disability caused by cubitus varus deformity. Sports disability was thought to be caused by complex elbow motion disorders due to the cubitus varus deformity, and the most common include sports that require throwing and swinging motions, followed by upper extremity–loading sports and swimming. The median period from the occurrence of injury in patients with sports disability was 9.0 [5.8 to 16.5] years, which corresponds to junior and senior high school when sports activities begin in earnest. Patients might become aware of their elbow

Figure 2



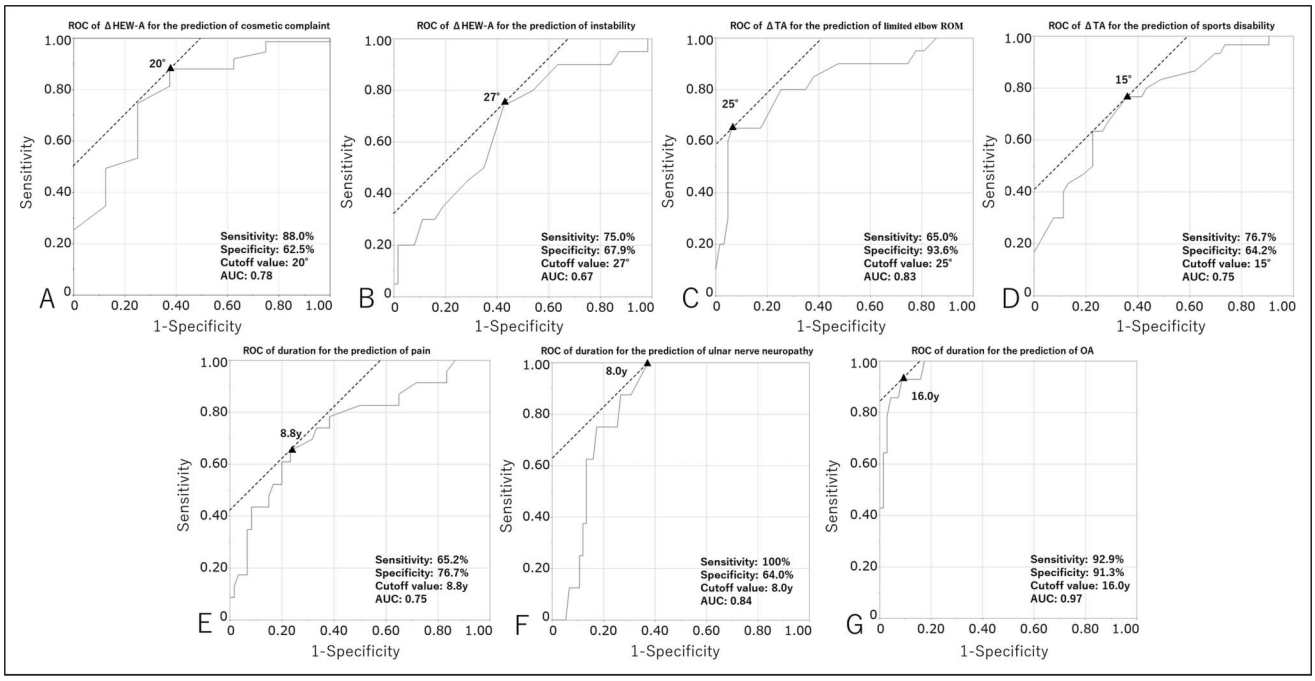
Graph showing odds ratios and 95% CIs for the association between complication events of cubitus varus deformity and parameters.
CI = confidence interval, OR = odds ratio

dysfunction only after start of sports activities. The cutoff value of the ΔTA for the onset of sports injury is $< 15°$, which might also support the finding that the cubitus varus deformity was left untreated because no symptoms such as elbow motion limitation were apparent.

The current findings focusing on the complications are relevant to decision making in corrective osteotomy. No study has clearly reported the cubitus varus deformity with the period related to complications, and no cutoff values of deformity angles that could cause complications have been established. Therefore, the indication for corrective osteotomy was determined based on patient complaints or the experience of the surgeons. This study suggests that a deformity of $\geq 20°$ in varus deformity and $\geq 25°$ in extension deformity compared with the normal side is one of the index values to consider corrective osteotomy.

This study has several limitations. First, the primary limitation of this study is the exclusion of asymptomatic cubitus varus deformity cases that did not require surgery. This led to an analysis based on a relatively small patient population who underwent corrective osteotomy. Although deformity cutoff values were determined in this study, the index values are based on characteristics of this biased cohort and might differ in a

Figure 3



Graphs showing receiver-operating characteristic curve analysis for the prediction of each event. The cutoff values of ΔHEW-A were 20° and 27° for cosmetic complaint (**A**) and instability (**B**), respectively. The cutoff value of ΔTA was 25° for the limited elbow range of motion (ROM) (**C**). The cutoff value of ΔTA was 15° for sports disability (**D**) (ΔTA less than 15° predicts the sports disability). The cutoff values of duration were 8.8, 8.0, and 16.0 years for pain (**E**), ulnar neuropathy (**F**), and osteoarthritis (**G**), respectively. AUC = area under the curve, HEW-A = humerus-elbow-wrist angle, ROC = receiver-operating characteristic

larger study group that includes asymptomatic cubitus varus cases. However, because most patients with minor deformities or no symptoms do not seek hospital care, such bias in the cohort is unavoidable.

Second, the actual period of complication onset might be shorter than indicated by the results of this study because the survey period was defined from the date of injury to the date of corrective osteotomy. In addition, sports disabilities were assessed based on patient complaints rather than being quantified. However, patients might have difficulty recalling the time of occurrence of complications. Thus, it is crucial to investigate symptoms at the time of surgery because it helps to avoid overestimate the onset time of symptoms.

Conclusion

A varus deformity of ≥20° has psychological effects on the patient owing to the presence of cosmetic problems. An index of risk for the development of elbow instability is a ≥27° varus deformity, and an extension deformity of ≥25° is an index of risk for elbow motion restriction. The treatment of cubitus varus deformity should be also determined considering that the patient may become aware of the elbow disability only after starting sports and the risk of late complications such as pain, ulnar neuropathy, and elbow OA.

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