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Original Article

Differences in Risk Factors for Rotator Cuff Tears between Elderly Patients and Young Patients

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It has been unclear whether the risk factors for rotator cuff tears are the same at all ages or differ between young and older populations. In this study, we examined the risk factors for rotator cuff tears using classification and regression tree analysis as methods of nonlinear regression analysis. There were 65 patients in the rotator cuff tears group and 45 patients in the intact rotator cuff group. Classification and regression tree analysis was performed to predict rotator cuff tears. The target factor was rotator cuff tears; explanatory variables were age, sex, trauma, and critical shoulder angle ≥ 35°. In the results of classification and regression tree analysis, the tree was divided at age 64. For patients aged ≥ 64, the tree was divided at trauma. For patients aged < 64, the tree was divided at critical shoulder angle ≥ 35°. The odds ratio for critical shoulder angle ≥ 35° was significant for all ages (5.89), and for patients aged < 64 (10.3) while trauma was only a significant factor for patients aged ≥ 64 (5.13). Age, trauma, and critical shoulder angle ≥ 35° were related to rotator cuff tears in this study. However, these risk factors showed different trends according to age group, not a linear relationship.

Key words: rotator cuff tears, risk factor, critical shoulder angle, trauma, classification and regression tree analysis

The etiology of rotator cuff tears (RCTs) is multifactorial. Several risk factors such as aging [1-3], trauma [4,5], and scapula morphology [6-9] are associated with RCTs. Critical shoulder angle (CSA) has been reported to be a significant risk factor for RCTs [8,10]. CSA develops due to a combination of glenoid inclination and acromial coverage. A higher CSA causes RCTs [11] because the supraspinatus force increases [12] and humeral head translation occurs [13]. Moor *et al.* [14] reported that age, trauma, and CSA could strongly predict RCTs in a linear regression model.

In general-population epidemiological studies, the frequency of RCTs appears to increase with age [1,2], but the relationship is not linear. Furthermore, the pathogenetic mechanism may be different in young and elderly patients [15]. It is difficult to interpret a linear regression model if the risk factors differ according to age. Nonlinear regression analysis such as classification and regression tree (CART) analysis is beneficial in situations where the risk factors are not linear [16].

It is unclear whether the risk factors are the same at all ages or differ between young and older populations. Indeed, clarifying the risk factors for each age group might be useful for the prevention of RCTs. In this study, we examined the risk factors for RCTs using CART analysis as a means of nonlinear regression analysis [16].

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Materials and Methods

Study subjects. From January 2016 to December 2016, consecutive patients that visited a particular orthopaedic clinic outpatient facility were recruited. Patients who had had shoulder joint symptoms lasting for at least 1 month, true antero-posterior radiographs of their shoulders, and magnetic resonance images (MRI) were included. Exclusion criteria included age younger than 18 years, history of surgery on the shoulders, and neurological diseases such as cervical spine disease. Patients were separated into 2 groups according to the presence of RCTs or intact rotator cuffs, and both groups were evaluated. RCTs were diagnosed using MRI, which was performed with a 0.3-T unit (Hitachi, Chiba, Japan). Three-directional T2-weighted images with oblique coronal, oblique sagittal, and transverse planes were obtained. Interpretation of radiophotography and MRI and diagnosis were made by 2 experienced orthopedic surgeons specializing in shoulder joints with over 30 years of experience (T.H. and H.M.).

Measurement of parameters. For validation purposes, 2 observers (A.W. and Q.O.) independently assessed all radiographs, and both observers were blinded to the patients' MRI findings. In the true antero-posterior radiographs, CSA was measured twice (Fig. 1). Each observer performed the same measurements, blinded to the other's findings. Radiophotography was performed using Shimadzu RAD speed Pro (Shimadzu, Kyoto, Japan), and CSA was measured using FCR CAPSULA-2 (Fujifilm, Tokyo, Japan).

For a survey of trauma, it was confirmed whether there had been an apparent trauma injury. Cases with symptoms triggered directly by a traumatic injury event (such as a fall, lifting of a heavy object, traffic trauma, *etc.*) were defined as "traumatic event yes," and cases in which symptoms developed spontaneously without any preceding trauma were defined as "traumatic event no."

For considering the relationship between occupation and RCTs, information regarding the subjects' occupation was retrospectively extracted from medical records (if available): in particular whether he/she is a farmer.

Statistical analyses. The intra-class correlation coefficient (ICC) with 95% confidence intervals (CIs) was calculated for the intra- and inter-observer reliability in the measurement of CSA.

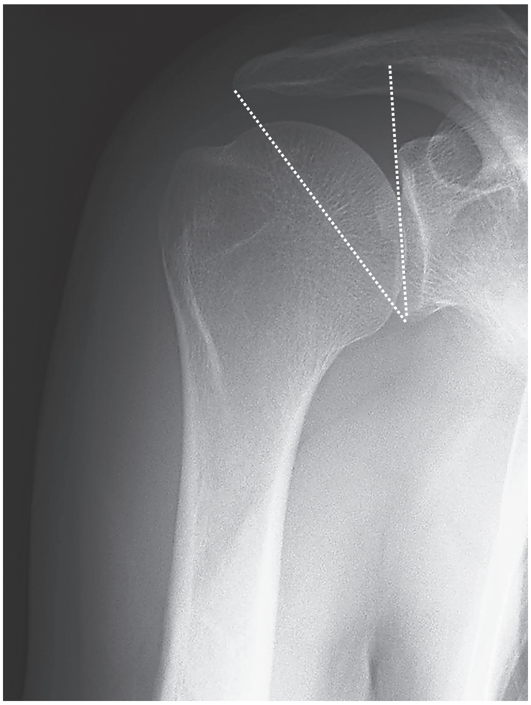

Fig. 1 The critical shoulder angle; between a line connecting the superior and inferior border of the glenoid fossa and another connecting the inferior border of the glenoid with the most inferolateral point of the acromion.

CART analysis was performed to predict RCTs. Age was entered as a continuous variable and the presence or not of an RCT, sex, trauma, and CSA (cut off; 35°) [8,10,11] were entered as binary variables. The target factor was RCTs (yes/no); explanatory variables were age, sex, trauma (yes/no), and CSA $\geq$ 35° (yes/no).

CART analysis was performed with reference to the RPART library in R (version 3.2.0), which is an established computational software for implementing CART, as well as with reference to recent studies using the same method [17,18]. Briefly, CART begins with the total sample, which is divided into 2 subgroups, in this case to determine the predictors for RCTs, and further divided into smaller groups by selecting the variable for the best split point. To determine the best size for the tree, pruning was performed with the "one standard error rule" [16,19]. The main point of the "one standard error rule" is comparable with the best model [20].

The odds ratios for various risk factor of age, CSA, and trauma were calculated in relation to RCTs. All statistical significance levels were set at 0.05. All statistical analyses were performed using R (Version 3.2.0).

Ethics. This study was approved by the institutional ethics committee of Konan Women's University. Written, informed consent for participation in this study was not obtained from the patients because this study was retrospective in nature and analyzed anonymously. The study was conducted in compliance with the Declaration of Helsinki.

Results

During the study period, 142 consecutive patients were enrolled; 32 were excluded from the analyses for the following reasons: <18 years ($n=24$), surgical history ($n=1$), and neurological disease ($n=7$). Finally, 110 patients met the inclusion criteria. There were 65 patients in the RCTs group and 45 patients in the non-RCTs group (Table 1). There were no significant differences in the number of traumatic injury events between the 2 groups. However, patients with RCTs had significantly greater age and more prevalent CSAs ≥ 35° than those in the non-RCTs group.

Both ICC (1,1) and ICC (2,1) were 0.99 (95%CI [0.97-1.00]) for CSA.

According to the results of CART analysis, the tree that followed the "one standard error rule" was divided into 4 subgroups. The tree is shown in Fig. 2, and the CART division chart is shown in Fig. 3. First, the tree was divided at age 64. The number of patients with RCTs in the group aged ≥ 64 was significantly higher than in the group aged < 64. For patients aged ≥ 64, the tree was divided at trauma. For patients aged < 64, the tree was divided at CSA ≥ 35°. Sex showed no relationship to RCTs.

We calculated the odds ratios for CSA and trauma for patients aged ≥ 64, < 64, and for all ages (Table 2) since the tree was first divided at age 64. The odds ratio for CSA was significant for all ages (5.89, 95%CI [2.4-15.3]), and for patients aged < 64 (10.3, 95%CI [1.8-79.5]), but not for patients aged ≥ 64. The odds ratio for trauma was only significant for patients aged ≥ 64 (5.13, 95%CI [1.2-31.2]).

The retrospective investigation of the occupation of the subjects revealed that farmers comprised 23% of the RCTs group and 11% of the non-RCTs group. However, the occupations of 41% of all subjects were unknown.

Discussion

This study provides 2 important clinical suggestions. Our results support recent evidence that age, trauma, and CSA are risk factors for RCTs. These risk factors showed different trends according to age group, but the relationship was not linear. That is, RCTs were related to CSA in patients aged < 64, and were related to trauma and aging itself in patients aged ≥ 64.

CART analysis showed that the strongest risk factor for RCTs was age. CSA ≥ 35° and trauma were also risk factors. A recent study suggested that a combination of age, trauma, and CSA can predict RCTs, and these predictions were almost 90% accurate for distinguishing patients with intact rotator cuffs from those with supraspinatus tears [14]. Several pieces of evidence suggest that aging leads to progressive degeneration of the rotator cuff and further, to RCTs [3,21-23]. Recent epidemiological surveys also indicated that aging is a significant risk factor for RCTs [1,2]. Furthermore, prior studies reporting that a large CSA was a strong predictor for RCTs are supported both theoretically and

Table 1 Summary of each parameter

	Total (n = 110)	RCT(+) (n = 65)	RCT(−) (n = 45)	*P* value
Age, mean (s.d.)	66.2 (10.5)	69.5 (7.9)	61.4 (12.3)	**< 0.001**
range	38–88	51–84	38–88	
Sex; female, n (%)	51 (46%)	28 (43%)	23 (51%)	0.44
Traumatic events yes, n (%)	49 (45%)	33 (51%)	16 (36%)	0.12
CSA, mean (s.d.)	33.4 (3.7)	34.4 (3.5)	32.1 (3.5)	**< 0.001**
CSA ≥ 35°, n (%)	35 (31%)	27 (42%)	8 (18%)	**0.01**
Job-farmers, n (%)	20 (18%)	15 (23%)	5 (11%)	
-not farmers, n (%)	45 (41%)	22 (34%)	23 (51%)	
-unknown, n (%)	45 (41%)	28 (43%)	17 (38%)	

CSA, critical shoulder angle; RCT(+), rotator cuff tears group; RCT(−), intact rotator cuff group; Age, CSA: *t*-test between RCT(+) group and RCT(−) group; Sex, Tranmatic events, CSA ≥ 35°: Fisher's exact test between RCT(+) group and RCT(−) group.

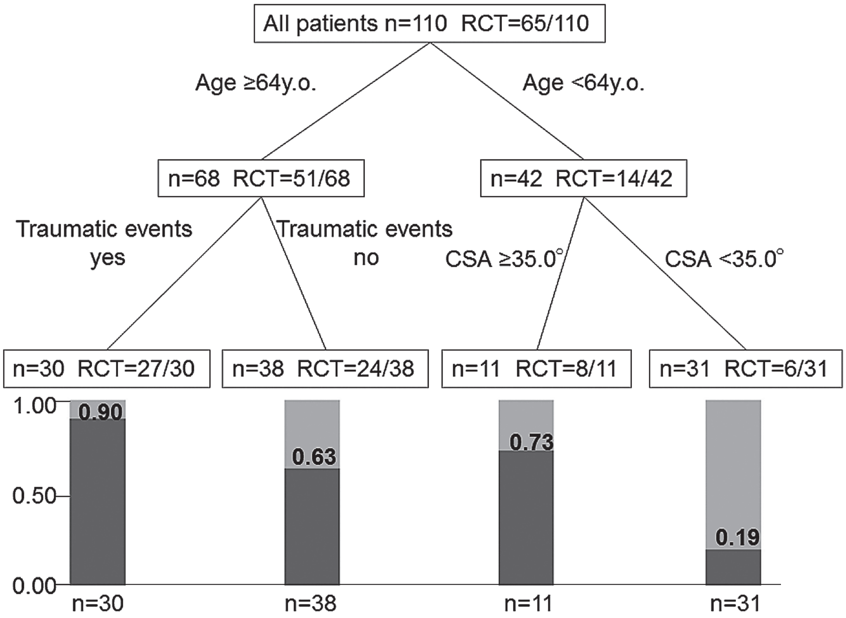

Fig. 2 Classification and regression tree results using the following variables: age, a critical shoulder angle of 35° or more, traumatic injury event. Complexity parameter (CP) = 0.045 for the tree followed "one standard error rule" is shown. The numerators indicate number of rotator cuff tears, and the denominators indicate the total number of cases in the subgroup.

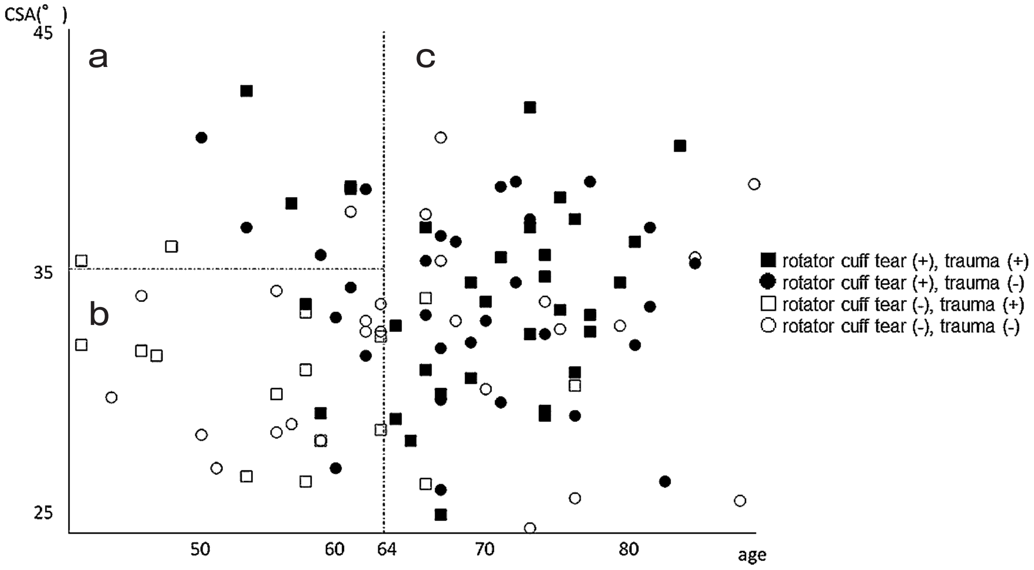

Fig. 3 Scatter plot of age, critical shoulder angle, traumatic injury event, and rotator cuff tears. The risk cutoff for age is 64 years and for critical shoulder angle is 35°. Closed (black) symbols indicate subjects with rotator cuff tears, opened (white) symbols indicate subjects with intact rotator cuff. Squares indicate "traumatic event yes", circles indicate "traumatic event no" (e.g.; closed square (■) is a subject with "traumatic event yes" and rotator cuff tears, open circle (○) is a subject with "traumatic event no" and intact rotator cuff). If aged < 64, the risk factor for rotator cuff tears is critical shoulder angle; *i.e.*, whether the subject falls within plot area a or b. In those aged ≥ 64, the only risk factor was traumatic event; *i.e.*, square or circle in area c.

epidemiologically [8,10-13,24]. Our results coincide with many of the earlier studies.

More importantly, the second clinical suggestion is that these risk factors showed different trends according to the age group; *i.e.*, RCTs were related to CSA in patients aged < 64, and were related to trauma and age in patients aged ≥ 64. Our CART analysis results suggest that CSA ≥ 35° is a risk factor in all ages and especially, in patients aged < 64, with respective odds ratios of 3.68 and 10.3. Trauma was a risk factor only in

Table 2 Summary of odds ratio of each risk factor

	Odds ratio	95%CI	*P* value
Total ($n = 110$)			
age ≥ 64	5.89	2.4 to 15.3	**< 0.001**
CSA $\geq 35°$	3.68	1.4 to 10.6	**0.004**
Traumatic events yes	1.86	0.8 to 4.4	0.12
age ≥ 64 ($n = 68$)			
CSA $\geq 35°$	1.67	0.5 to 7.0	0.57
Traumatic events yes	5.13	1.2 to 31.2	**0.01**
age < 64 ($n = 42$)			
CSA $\geq 35°$	10.3	1.8 to 79.5	**0.002**
Traumatic events yes	0.86	0.2 to 3.8	1

CSA, critical shoulder angle; 95%CI, 95% confidence interval.

patients aged ≥ 64, with an odds ratio of 5.13. These findings provide useful clinical information. The CSA in patients aged < 64 should be checked using radiophotographs. If the CSA is $\geq 35°$ regardless of whether or not a traumatic event has occurred, RCTs should be suspected. Therefore, it is recommended to examine these patients by MRI or ultrasound echo for RCTs. In contrast, if CSA is $< 35°$, the possibility of RCTs would be low. Patients aged ≥ 64 should be suspected for RCTs first. Furthermore, if the symptoms were triggered directly by a traumatic injury event, the possibility of RCTs should be regarded as extremely high.

A recent study reported that the CSA in degenerative RCTs was significantly larger than that in traumatic RCTs, and that CSA was related to the former but not to the latter [25]. Based on our results in combination with recent findings, there appear to be many degenerative RCTs in patients aged < 64 in this study, as there was a strong relationship between RCTs and CSA but no relationship with trauma in individuals aged < 64. Further, Moor *et al.* reported that the odds ratio for CSA $\geq 35°$ was 10.8 for degenerative RCTs [10]. The odds ratio of 10.3 obtained in this study was at the same level only for patients aged < 64. In contrast, several mechanisms other than CSA that lead to the occurrence of RCTs in patients aged ≥ 64 were likely included in this study. Indeed, trauma was related to RCTs in patients aged ≥ 64 only. These results suggest that fall prevention and the avoidance of heavy object lifting may reduce RCTs in individuals aged ≥ 64, but not in those aged < 64.

Inconsistent with our study, a recent review reported that the occurrence of RCTs in younger patients (aged < 40) is related to trauma, whereas the occurrence in elderly patients is related to degeneration [15]. This discrepancy could be partially explained by regional characteristics, as many active elderly people were originally highly active. In the research population, 32.2% were elderly individuals (defined as ≥ 65 years old) [Statistics Bureau, Ministry of Internal Affairs and Communications: http://www.stat.go.jp/data/jinsui/2014np/ (accessed April 12, 2017)], and the proportion of primary industry workers (agriculture, fishery, and forestry) was 10.9% [Statistics Bureau, Ministry of Internal Affairs and Communications: http://www.stat.go.jp/data/kokusei/2010/kihon2/pdf/gaiyou.pdf (accessed April 12, 2017)]. Additionally, 20.2% of the elderly population was still engaged in some type of work, 35% of whom were farmers. Therefore, approximately 7% of the elderly in the study area were farmers [Kochi prefecture: http://www.pref.kochi.lg.jp/soshiki/060201/files/2015021200184/file_201512611511_1.pdf (accessed April 12, 2017)]. In this study, at least 18% of all subjects and 23% of the RCTs group were farmers. It has been suggested that labor-intensive occupations are a significant risk factor for poor postoperative outcomes for RCTs [26]. Therefore, RCTs may be a "social disease" strongly affected by the industrial structure as there are many active elderly farmers. This hypothesis is meaningful for our aging society with many elderly farmers.

There were several limitations in this study. First, many patients lacked data on industrial classification, and we did not analyze the industry structure because this was a retrospective observation study using only existing medical records. However, our main focus in this study was age, trauma, and CSA; industrial classification was the secondary aim. Furthermore, in our study, it is possible that farmers are included among the subjects whose occupation is unknown. That would only increase the proportion of farmers, which is consistent with the increasing proportion of active elderly farmers in our society. Although our hypotheses on regional characteristics could be partially supported, our findings need to be confirmed in a future study. Second, the study covered only outpatients and did not include patients with asymptomatic RCTs. RCTs in individuals aged ≥ 64 were strongly related to trauma such as falling. However, individuals who are asymptomatic after falling will not visit a clinic. Therefore, the frequency of traumatic RCTs is unknown. Finally, we could not discuss the risk factors for RCT occurrence in much younger patients, because patients younger than 40 years were not included [15]. Our results suggest that trauma is related only to RCTs in the elderly, but not in younger patients. It is unknown whether the same is true for individuals younger than 40 years.

In conclusion, age, trauma, and CSA were related to RCTs in this study; however, these risk factors showed different trends according to the age group, and not a linear relationship. RCTs may be a "social disease" highly related to the industrial structure, reflected by the presence of many highly active elderly farmers. Reports on different industrial structures are unavailable and further studies are required.

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