Does a Comparison View Improve the Reliability of Staging Wrist Osteoarthritis?

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Abstract

Background: Radiological grading of wrist osteoarthritis associated with scaphoid nonunion advanced collapse (SNAC) can be difficult. A comparison radiograph of the contralateral healthy wrist and an educational training in the various SNAC stages may improve reliability. Our purposes were to evaluate the difference in the reliability: (1) between observers who rate SNAC wrists with and without a comparison radiograph; and (2) between observers who receive training prior to ratings and those who do not. **Methods:** In this cross-sectional survey study, 82 fully trained orthopedic or hand surgeons rated anteroposterior radiographs of 19 patient wrists following a scaphoid nonunion based on SNAC stages 0 to 4. Observers were randomized online in 4 groups: one group rated unilateral views without training, a second group unilateral views with training, a third group bilateral views without training, and a fourth group bilateral views with training. Training included a 1-page clarification of the SNAC stages. Interobserver agreement was calculated using kappa statistics. **Results:** There was no significant difference between agreement between observers who rated unilateral radiographs ($\kappa = 0.55$) and who rated bilateral radiographs ($\kappa = 0.58$) ($P = .14$), nor between agreement between observers who received training ($\kappa = 0.59$) and who did not ($\kappa = 0.54$) ($P = .058$). **Conclusions:** The use of an additional comparison view and/or training does not seem to be clinically relevant in SNAC staging. There is room for improvement in the way we assess patients with SNAC wrists.

Keywords: scaphoid nonunion, scaphoid, osteoarthritis, SNAC, comparison view

Introduction

Nonunion is a common reason for surgery after a scaphoid fracture.⁴ The patient's symptoms, the remaining wrist motion, and the extent of the osteoarthritis on radiographs are factored into the decision between an attempt to get the scaphoid healed and a salvage procedure.⁵ Accurate and reliable radiological evaluation of osteoarthritis would therefore be helpful in both research and patient care.

In daily practice, osteoarthritis with scaphoid nonunion is usually assessed using radiographs¹⁶ and is staged as so-called scaphoid nonunion advanced collapse (SNAC) according to Vender et al.¹⁹ Typically, degenerative changes start in radioscaphoid articulation, with narrowing and osteophyte formation between the radius and the distal fragment with the proximal fragment spared (stage I). Next is midcarpal arthrosis with changes between the capitate and the proximal fragment (stage II), and between capitate and lunate (stage III). At its worst, the radiolunate joint is involved as well (stage IV).¹⁷ This pattern differs slightly from the pattern observed in scapholunate advanced collapse (SLAC) wrists,²¹ in which degenerative changes occur at the entire radioscaphoid joint in the early stages.

Recent studies^{13,20} concluded that SNAC staging based on anteroposterior (AP) radiographs has limited reliability. One possibility is that it can be difficult to distinguish between early stages of osteoarthritis and normal anatomy. A comparison view of the contralateral healthy wrist might improve the reliability of radiological grading of SNAC wrist osteoarthritis. Moreover, differentiating between SNAC stages may be affected by the surgeon's knowledge and awareness of the stages. Consensus on the definition of the various SNAC stages may improve reliability.³ We believe that this could be enhanced by establishing an educational training in SNAC stages prior to rating.

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Table 1. Baseline Characteristics of Patients (n = 19).

Characteristics of patients	n (%) / mean (range)
Sex	
Male	18 (95)
Female	1 (5)
Age (y)	37 (18-81)
Nonunion side	
Right	16 (84)
Left	3 (16)
Treatment	
Conservative	3 (16)
Reconstruction	9 (47)
Salvage	7 (37)

In this study, we evaluated the ability of radiographs of the healthy opposite wrist (ie, comparison view) to improve reliability in staging SNAC wrist osteoarthritis. In addition, we evaluated whether a training about the SNAC pattern and its different stages would improve reliability. Our primary null hypothesis was that there is no difference in the reliability in SNAC staging between observers who rated osteoarthritis associated with scaphoid nonunion with and without a comparison radiograph. Our secondary null hypothesis was that there is no difference in the reliability in SNAC staging between observers who receive training in the SNAC classification and those who do not prior to rating.

Materials and Methods

Study Design, Setting, and Participants

The study protocol was approved by the institutional review board. Members of the Science of Variation Group (SOVG) with special interest in hand and wrist surgery including orthopedic and hand surgeons (N= 385) were invited by email to complete a 4-question survey on radiological evaluation of the osteoarthritic development in wrists following a scaphoid nonunion. The SOVG is an international collaboration of fully trained orthopedic, trauma, and plastic surgeon observers that studies variation in the definition, classification, and treatment of human illness without financial incentives. Of the invited members, 82 (21%) completed the survey. Because many SOVG members listed in the database are not active participants and emails in the list are not updated, the participation rate is not similar to a true response rate. The survey was developed in an online survey tool, SurveyMonkey (Palo Alto, California).

We selected 19 consecutive patients 18 to 81 years old with an ununited fracture of the scaphoid (Table 1), treated at 1 of 4 institutions in the United States and the Netherlands between 2000 and 2014, for which AP radiographs of both the affected and contralateral healthy wrists were available

(Figure 1). Both proximal and waist fractures were included as their associated SNAC stages progress in the same order throughout the carpal wrist following a scaphoid nonunion.¹² The time between injury and radiograph was more than 6 months (range, 7 months to >25 years). In case of unknown date of injury, we followed the diagnosis based on the radiological reports (eg, “old scaphoid fracture”) to identify nonunion. The included patient wrists represented a full spectrum from no osteoarthritic signs to severe osteoarthritic deformation.

We constructed a training including a 1-page introduction text with illustration, clarifying the SNAC classification according to Vender et al¹⁹ (see the Appendix). This training was shown prior to the radiological evaluations.

Randomization

Participating observers were randomized by entering the survey through an automated software algorithm in 4 equal size groups. One group rated unilateral views without training, a second group rated unilateral views with training, a third group rated bilateral views without training, and a fourth group rated bilateral views with training. As per standard SOVG protocol, observers were not informed about this randomization process. Participating observers provided their sex, location of practice, number of years in practice, and whether they supervised trainees (Table 2).

Power Analysis

In 2 previous interobserver studies, the kappa value regarding agreement in SNAC staging based on unilateral AP views was, on average, 0.2.^{13,20} We would consider an increase of kappa value by 0.2 as clinically relevant. Using the *kappa size* package in R statistics,¹⁴ we calculated that a minimum sample size of 18 patient wrists would provide 80% statistical power ($\beta = 0.20$; $\alpha = 0.05$) to detect a difference from $\kappa = 0.2$ to $\kappa = 0.4$, when at least 6 observers are involved, and the incidence of different SNAC stages (stage 0 to stage 4) is equally distributed.

Evaluation and Outcome Measures

Each observer was asked to classify SNAC osteoarthritis as follows: no arthritis, SNAC stage I, SNAC stage II, SNAC stage III, and SNAC stage IV. These SNAC stages were in accordance to Vender et al.¹⁹ We also asked observers to rate their confidence in their rating on a scale from 0 to 10 (0 = not at all confident; 10 = extremely confident). In addition, each observer was also asked whether there was (1) joint space narrowing in the radioscapoid joint area and (2) styloid pointing/osteophyte formation of the radius styloid. All observers evaluated the same 19 patients, in the same

Figure 1. Example of a standard anteroposterior radiograph of a wrist with an ununited fracture of the scaphoid, and comparison view of the opposite healthy side.

Note. SNAC = scaphoid nonunion advanced collapse.

Table 2. Baseline Characteristics of Participating Surgeons per Observer Group (n = 82).

	Unilateral view without training (n = 21), n (%)	Unilateral view with training (n = 21), n (%)	Bilateral view without training (n = 19), n (%)	Bilateral view with training (n = 21), n (%)
Sex				
Male	20 (95)	19 (90)	18 (95)	19 (90)
Female	1 (5)	2 (10)	1 (5)	2 (10)
Location of practice				
United States and Canada	13 (62)	12 (57)	12 (63)	12 (57)
Europe	4 (19)	2 (10)	6 (32)	6 (29)
Other	4 (19)	7 (33)	1 (5)	3 (14)
Years in practice				
0-5	9 (43)	9 (43)	6 (32)	6 (29)
6-10	2 (10)	4 (19)	5 (26)	5 (25)
11-20	8 (38)	5 (24)	5 (26)	7 (33)
21-30	2 (10)	3 (14)	3 (16)	3 (14)
Supervising trainees				
Yes	19 (90)	18 (86)	17 (89)	18 (86)
No	2 (10)	3 (14)	2 (11)	3 (14)

Note. Observers were randomized by entering the survey through an automated software algorithm into 4 groups on a 25/25/25/25 basis.

order of appearance. Observers could not skip questions. No patient information was provided.

Statistical Analysis

We calculated interobserver agreement among multiple observers using the adjusted Fleiss' kappa in the *rater* package⁷ in R statistics version 3.0.2 (The R foundation for Statistical Computing, Vienna, Austria). This adjusted Fleiss' kappa included a chance-correction¹¹ and a linear weighting. The generated kappa values were interpreted according to the guidelines of Landis and Koch⁹: A value of 0.01 to 0.20 indicates slight agreement; 0.21 to 0.40, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.80, substantial agreement; and 0.81 to 0.99, almost perfect

agreement. We compared values of the adjusted Fleiss' kappa between observer groups using a bootstrap method¹⁸ written in the statistical environment R.

Regarding confidence score, we calculated the mean score of each observer and tested whether these mean scores were normally distributed using the Shapiro-Wilk *W* test. In case of a normal distribution, independent student *t* test was used to test whether mean scores differ between observers. A 5% significance level was used for all analyses.

Results

There was no significant difference between agreement in SNAC staging between observers who rated unilateral radiographs ($\kappa = 0.55$) and who rated bilateral radiographs

Table 3. Results of Interobserver Agreement: Unilateral Versus Bilateral View; Nontraining Versus Training; Total Observers.

	Unilateral view (n = 42)	Bilateral view (n = 40)	P value	Nontraining (n = 40)	Training (n = 42)	P value	Total (N = 82)
SNAC classification							
Agreement, κ^a (95% CI)	0.55 (0.46-0.65)	0.58 (0.49-0.66)	.14	0.54 (0.46-0.62)	0.59 (0.49-0.69)	.058	0.56 (0.47-0.65)
Interpretation ^b	Moderate	Moderate		Moderate	Moderate		Moderate
Confidence, $\bar{x} \pm SD$	7.3 $\pm$ 1.3	7.2 $\pm$ 1.2	.56	7.1 $\pm$ 1.3	7.4 $\pm$ 1.2	.57	7.2 $\pm$ 1.2
Joint space narrowing							
Agreement, κ^a (95% CI)	0.40 (0.27-0.52)	0.37 (0.23-0.51)	.58	0.32 (0.20-0.44)	0.46 (0.31-0.61)	<.001	0.38 (0.25-0.52)
Interpretation ^b	Fair	Fair		Fair	Moderate		Fair
Styloid pointing							
Agreement, κ^a (95% CI)	0.40 (0.27-0.55)	0.44 (0.30-0.58)	.31	0.37 (0.25-0.49)	0.48 (0.33-0.64)	.008	0.43 (0.30-0.56)
Interpretation ^b	Fair	Moderate		Fair	Moderate		Moderate

Note. Bold indicates a P value <.05. SNAC = scaphoid nonunion advanced collapse; CI = confidence interval.

^aBased on the adjusted Fleiss' kappa.

^bBased on the Landis and Koch criteria.

^cBased on a scale from 0 to 10 (0 = not at all confident; 10 = very confident).

($\kappa = 0.58$) ($P = .14$) (Table 3). In addition, there was no significant difference between observers in decision confidence ($P = .56$), nor in agreement regarding joint space narrowing ($P = .58$) and styloid pointing/osteophyte formation ($P = .31$). Mean confidence scores were normally distributed.

There was no significant difference between agreement in SNAC staging between observers who received training ($\kappa = 0.59$) and who did not ($\kappa = 0.54$) ($P = .058$) (Table 3). In addition, there was no significant difference between observers in decision confidence ($P = .57$). Even though it was not part of the training, trained observers showed higher agreement regarding joint space narrowing ($P < .001$) and styloid pointing/osteophyte formation ($P = .008$).

Overall, the agreement in SNAC staging among observers was moderate ($\kappa = 0.56$). Overall confidence score was 7.2 ± 1.2 . Overall agreement among observers was fair regarding joint space narrowing ($\kappa = 0.38$), and moderate regarding styloid pointing/osteophyte formation ($\kappa = 0.43$) (Table 3). Based on the mean ratings of all observers, 5 of the 19 patients had SNAC stage 0 (no osteoarthritis), 5 SNAC stage 1, 4 SNAC stage 2, 3 SNAC stage 3, and 2 SNAC stage 4.

Discussion

In the treatment of unilateral wrist diseases, an image of the opposite healthy wrist is occasionally taken for comparison purposes.^{1,10,22} A comparison view might make the abnormality on the affected view more salient, and therefore easier to discriminate.⁸ In this study, we investigated whether the addition of a comparison view could improve the reliability of SNAC staging, and the role of the surgeon's basic knowledge about the SNAC classification. We found that SNAC staging was not improved by the addition of a

comparison view, nor by the addition of objective information about this classification prior to rating.

A limitation of this study is that the radiographs as seen by the observers in the online survey could not be magnified to highlight the specific details. However, showing images in a fixed format with similar quality enabled a reliable comparison between observers. On the contrary, the inability to magnify might have overshadowed the potential additional value of a comparison view and/or the specific SNAC classification training. Second, a potential inclusion bias could have been present, because we included only patients of whom radiographs were taken of both wrists. Nonetheless, based on the mean ratings of all observers, we confirmed that the included wrist images represented a full spectrum from no osteoarthritic signs to severe osteoarthritis. Third, a different training method might have led to different results. However, we consider the content of the training valid, as it was based on the original descriptions of Vender et al.¹⁹ In addition, we were unable to verify whether the observers who received the training actually have followed the training, and not simply clicked to the next page in the online survey. To improve adherence, we clearly instructed the observers to follow the training carefully. Finally, this study did not investigate the potential differences in surgical decision making between observers, as the treatment of a scaphoid nonunion cannot be selected based on SNAC staging alone. For adequate decision making, also the patient's symptoms, expectations, functional demands, and patient's and surgeon's preferences should be taken into account.⁵

Two previous interobserver studies^{13,20} investigated reliability in SNAC staging without the use of a comparison view. Both studies included, respectively, 5 and 4 observers, who rated 48 and 47 SNAC wrists according to the

classification of Vender et al.¹⁹ In general, agreement was unsatisfactory, showing kappa values ranging from 0.09 to 0.31, which is lower than our reported overall kappa value of 0.56. It is likely that this difference is caused by the difference in the applied kappa statistics. As SNAC staging is based on an ordinal scale ranging from no arthritis to severe arthritis, we used an adjusted Fleiss' kappa including a chance-correction and a linear weighting. This means that when evaluating agreement, a greater "penalty" would be applied if 2 SNAC stages chosen by the observers are farther apart. Post hoc, we applied also the standard Fleiss' kappa statistics, although considering it as a less suitable measure for our data set, resulting in a kappa value of 0.34, corresponding to the aforementioned kappa values found in literature.

We showed that there was no difference in the reliability in staging SNAC wrists between observers who received specific information about the pattern of degenerative arthritis in SNAC wrists and who did not. This suggests that the most surgeons interpreted SNAC classification in the same manner, or they use different interpretations but without clinical consequences. Only agreement regarding joint space narrowing and styloid pointing was higher in the trained group. However, these secondary results may be spurious, as associated measures were not part of the training.

Christensen et al⁶ proposed that the interpretation of radiographs showing a particular pathology involved a fast and a slow component. The fast component achieves detection of abnormalities almost instantaneously by comparing the observed radiograph with a previously learned concept of normal *in memory*. The slow component relies on a search using focused eye moment, which needs time and effort. Both components improve with experience. Showing a *real* comparison view to an experienced physician could be redundant and less effective than comparison with their *memory*. On the contrary, for less experienced physicians or medical students, a comparison view might make it easier to detect an abnormality, as they are likely to have a less developed concept of what is normal.^{2,8} In this study, we included only fully trained hand surgeons and orthopedic surgeons with special interest in hand and wrist surgery. This could have minimized the potential additional value of a comparison view and/or the specific SNAC classification training. The finding that all observer groups were sufficiently confident in SNAC staging (all groups scored above 7), irrespective to training, supports this thought.

There is room for improvement in the way we assess patients with SNAC wrists. The use of a comparison view, however, does not seem to be clinically relevant in SNAC staging, at least for fully trained surgeons. Still, the opposite side might have a potential diagnostic value for other measures in the evaluation of osteoarthritic wrists. For example, it may provide a better reference for quantitative estimations of carpal collapse based on the carpal height and the

carpal angles, compared with population data.¹⁵ For future studies, we would recommend focusing on assessing the osteoarthritic wrist using other imaging modalities such as magnetic resonance imaging (MRI) and computed tomography (CT), rather than additional views, such as lateral views, which might be confusing due to overlapping projection of carpal bones.

Authors' Note

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Ethical Approval

The Medical Ethics Review Committee of Massachusetts General Hospital approved this study (Protocol No: 2009P001019). The Medical Ethics Review Committee of Academic Medical Center confirmed that the Medical Research Involving Human Subjects Act (WMO) did not apply to this study, and an official approval of this study by the committee was not required (W15_131 # 15.0159).

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Appendix

Please read this introduction carefully:

Introduction SNAC classification

Untreated scaphoid nonunion leads to a pattern of osteoarthritic changes in the wrist known as scaphoid nonunion advanced collapse (SNAC), which was initially described by Vender et al. (1987).

In the first SNAC stage, osteoarthritic changes initiate at the radioscaphoid joint showing narrowing of the articular space between the styloid and distal scaphoid fragment, radial styloid pointing and dorsal osteophyte formation. In the second SNAC stage, midcarpal osteoarthritis occurs, which is manifested by narrowing of the joint space between the capitate and proximal nonunion fragment. In the third SNAC stage, narrowing of the capitulate joint space becomes visible indicating advanced midcarpal osteoarthritis. The fourth SNAC stage describes an advanced pancarpal osteoarthritis including in the radiolunate joint (Fig 1).

Figure 1: The SNAC classification include SNAC stage (0): no osteoarthritis; SNAC stage (I): radioscaphoid osteoarthritis; SNAC stage (II): midcarpal osteoarthritis, SNAC stage (III): advanced midcarpal osteoarthritis, and SNAC stage (IV): pancarpal osteoarthritis including radiolunate joint.

Statement of Informed Consent

The study was approved by our institutional review board and a waiver of informed consent was obtained.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publica-

tion of this article: One author (D.R.) certifies that he, or a member of his immediate family, has or may receive payments or benefits during the study period from AO North America (less than \$10 000; Paoli, Pennsylvania); AO International (less than \$10 000; Dübendorf, Switzerland); Biomet, Inc (less than \$10 000; Warsaw, Indiana); Medartis (less than \$10 000; Basel, Switzerland); Skeletal Dynamics LLC (less than \$10 000; Miami, Florida); and Wright Medical Technology, Inc (less than

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