RADIOGRAPHIC SIGNS OF UNION OF SCAPHOID FRACTURES

AN ANALYSIS OF INTER-OBSERVER AGREEMENT AND REPRODUCIBILITY

J. J. DIAS, M. TAYLOR, J. THOMPSON, I. J. BRENKEL, P. J. GREGG

From Leicester Royal Infirmary

Inter-observer agreement and reproducibility of opinion were assessed for the radiographic diagnosis of union of scaphoid fractures on films taken 12 weeks after injury. Weighted kappa statistics were used to compare the opinions of eight senior observers reviewing 20 sets of good quality radiographs on two occasions separated by two months.

There was poor agreement on whether trabeculae crossed the fracture line, whether there was sclerosis at or near the fracture and on whether the proximal part of the scaphoid was avascular. As a consequence, agreement on union also was poor; it appears that radiographs taken 12 weeks after a scaphoid fracture do not provide reliable and reproducible evidence of healing.

Fractures of the waist of the scaphoid are usually treated in plaster for 6 to 12 weeks. The decision to start mobilising the wrist is made at that time and is based on the absence of "significant" tenderness in the anatomical snuff box (London 1961) and on radiographic "evidence" of union.

The presence of trabeculae crossing the fracture or sclerosis at the site are thought to reflect fracture healing, and these two signs are the only objective assessments of union in most published studies (Russe 1960; Leslie and Dickson 1981). Radiographs of the scaphoid at 12 weeks, however, can be difficult to interpret (Herbert and Fisher 1984). Trabeculae may appear to cross the fracture line if the beam is not exactly in the plane of the fracture, and sclerosis of the fracture line may appear as a single line or as a double line, perhaps produced by overlap of images (Lindgren 1949).

These factors led us to question whether radiographs of scaphoid fractures at 12 weeks provide a reliable and objective indication of union. Our study was, therefore, designed to determine the reliability of the radiographic diagnosis of union of such fractures by testing the degree of inter-observer agreement.

METHOD

Of 212 sets of radiographs of fractures of the waist of the scaphoid taken at about 12 weeks after injury, 20 of good quality were selected at random. Each set included at least four views (Russe 1960): postero-anterior, lateral, semi-pronated and semi-supinated.

Eight observers were tested: four orthopaedic consultants and four consultants in radiology. Each was presented with the 20 sets of radiographs, labelled A to T and each was asked to answer four questions for each set; these, and the five possible answers, are listed in Table I.

Two months later the 20 sets of radiographs were relabelled from 1 to 20 and presented to the same eight observers, who had no prior knowledge that they would be asked to review the films again.

Data was then analysed and expressed in terms of inter-observer agreement in pairs. Calculation was by weighted kappa statistics (Landis and Koch 1977) so that the degree of disagreement was taken into account and allowance was made for chance agreement. Weighted kappa values can vary from -1.0 (complete disagreement) through 0 (chance agreement) to +1.0 (complete agreement).

RESULTS

One example of a single view from a set of radiographs taken 12 weeks after injury is shown in Figure 1; this produced considerable disagreement, with the spread of opinions shown in Table I. For all 20 sets of radiographs, the degree of agreement between each pair of observers was calculated. An example is given in Table II; this demonstrates the level of agreement between one observer and each of the remaining seven observers. The weighted average inter-observer agreement, κ , was

J. J. Dias, FRCS, Lecturer
M. Taylor, MB ChB, Senior House Officer
I. J. Brenkel, FRCS, Lecturer
P. J. Gregg, MD, FRCS, Professor
University Department of Orthopaedic Surgery, Leicester Royal Infirmary, Infirmary Square, Leicester LE1 5WW, England.

J. Thompson, PhD, Lecturer in Epidemiology
Department of Ophthalmology, Leicester Royal Infirmary, Infirmary Square, Leicester LE1 5WW, England.

Requests for reprints should be sent to Mr J. J. Dias.

© 1988 British Editorial Society of Bone and Joint Surgery
0301-620X/88/2065 \$2.00
J Bone Joint Surg [Br] 1988;70-B:299-301.

calculated on the basis of a similar analysis for each of the other observers.

This inter-observer agreement was calculated for each question. On whether there were trabeculae crossing the fracture line, κ was 0.104, for sclerosis at the fracture line it was 0.371 while for proximal scaphoid avascularity it was 0.214. As regards fracture union, the inter-observer agreement was 0.386 (Table III). Even when the five possible answers to each question were regrouped as (1) definitely or probably yes, (2) don't know and (3) definitely or probably not there was no improvement in inter-observer agreement (Table III).

The degree of agreement between the opinions of each observer at his first and at his subsequent reviews of the same set of radiographs is presented in Table IV. The ability of the eight observers to reproduce their own opinion regarding trabeculae crossing the fracture line ($\kappa=0.297$), sclerosis at the fracture line ($\kappa=0.576$) and proximal scaphoid avascularity ($\kappa=0.414$) was too poor for the use of these signs to assess bony union. The reproducibility as regards to union of the fracture was better ($\kappa=0.705$), though as mentioned above inter-observer agreement for this was poor ($\kappa=0.386$).

DISCUSSION

Russe (1960) suggested that fractures of the scaphoid should be immobilised until radiographs demonstrated

definite signs of union, which included the presence of bony trabeculae bridging the defect and increased density at the site of, or on each side of, the fracture line. These signs have been used as an objective method of assessing union in many reports (Stewart 1954; Leslie and Dickson 1981).

Our study has shown that even 12 weeks after injury there was very poor agreement between observers on these factors and therefore on union of the fracture, with an unacceptably low degree of reproducibility. The poor levels of agreement were surprising, since the 20 sets of radiographs had been chosen to reflect clinical practice and were all of good quality; a situation better than that in a busy fracture clinic. We therefore feel that radiographs obtained 12 weeks after injury, cannot be reliably and reproducibly used to assess union of a scaphoid fracture.

The clinical implications of this unreliability have a medicolegal significance. London (1961) recognised the difficulty of interpreting radiographs and suggested that more emphasis be placed on careful examination of the injured wrist. In our opinion the decision to discontinue immobilisation after 8 to 12 weeks should be based on the absence of marked tenderness in the scaphoid region and the absence of a clear radiographic gap at the fracture line. However, as the interpretation of radiographs is so unreliable, we advise continued follow-up for a further three to six months. Patients such as motor mechanics

Fig. 1

Postero-anterior view of a fracture of the waist of the scaphoid taken 12 weeks after injury. Conflicting opinions of this radiograph are given in Table I.

Table I. Opinions given at eight initial and eight subsequent reviews of the scaphoid fracture shown in Figure 1

	Definitely yes	Probably yes	Don't know	Probably not	Definitely not
Has the fracture united?	4	3	0	9	0
Are there trabeculae crossing the fracture line?	4	1	1	6	4
Is there sclerosis at the fracture line?	11	2	0	1	2
Is there avascularity of the proximal part?	6	3	0	3	4

Table II. The weighted kappa values* for agreement between Observer 1 and each of the other seven observers

Observer	Union	Trabeculae crossing	Sclerosis	Avascular necrosis
2	0.173	0.091	0.457	0.320
3	0.322	-0.057	0.597	0.196
4	0.528	0.528	0.583	0.066
5	0.226	0.142	0.543	0.318
6	0.113	0.370	0.183	0.091
7	0.479	0.077	0.338	0.455
8	0.239	0.204	0.556	0.000

* weighted kappa statistics show (-1) for complete disagreement (0), for chance agreement and (+1) for complete agreement (Landis and Koch 1977). Each observer was paired with the others in the same way

Table III. Average agreement between observers on radiographic signs of union of scaphoid fractures at 12 weeks, assessed by the five original possible replies and by combining "definitely" and "probably" to give three possible replies (see text)

	Five replies	Three replies
Has the fracture united?	0.386	0.387
Are there trabeculae crossing the fracture line?	0.104	0.175
Is there sclerosis at the fracture line?	0.371	0.395
Is there avascularity of the proximal part?	0.214	0.028

Table IV. Reproducibility by each observer of his opinion* on radiographic signs of union of scaphoid fractures

Observer	Union	Trabeculae crossing	Sclerosis	Avascular necrosis
1	0.926	0.477	0.531	0.322
2	0.579	0.654	0.627	0.653
3	0.550	-0.061	0.677	0.367
4	0.679	0.603	0.558	0.167
5	0.847	0.845	0.490	0.462
6	0.257	0.267	0.115	0.000
7	0.556	0.470	0.357	0.563
8	0.525	0.525	0.761	0.000
Weighted average	0.705	0.297	0.576	0.414

* the level of agreement between the initial opinion and that given two months later was calculated for each observer. The weighted average for all eight observers is also given (Landis and Koch 1977)

Table V. The results from large retrospective series of fresh scaphoid fractures

Author	Number of fractures	Time of radiograph (weeks)	Non-union (per cent)
Stewart 1954	320	8 to 12	5
Russe 1960	220	6 to 12	3
London 1961	227	8 to 12	5
Leslie and Dickson 1981	222	6 to 8	5

who make heavy use of the hand and wrist should perhaps be provided with a removable wrist splint for a period after the removal of plaster.

Our results also cast doubt on the conclusions drawn from previous studies which have been based on radiographic evaluation of union at or before 12 weeks (Table V). Most of the studies which include large numbers of cases suggest that 95% of fresh scaphoid fractures will unite uneventfully. By contrast, several recent reports (Cooney, Dobyns and Linscheid 1980a,b; Herbert and Fisher 1984) have suggested that the incidence of non-union is 25% to 50% and some authors (Mulder 1968; Cooney et al. 1980a,b) have been able to collect large numbers of patients with established pseudarthroses. The exact incidence of non-union of a clear gap at the fracture line on radiographs taken one year after injury (Maudsley and Chen 1972), is unknown.

Conclusion. Radiographs obtained 12 weeks after injury cannot be used reliably and reproducibly to assess union of a fractured scaphoid. Radiograph criteria should not be used as an objective assessment of union in clinical studies.

We would like to thank the eight consultants in the departments of orthopaedic surgery and radiology of the Leicester group of hospitals who reviewed the set of radiographs conscientiously, even the second time round.

REFERENCES

- Cooney WP, Dobyns JH, Linscheid RL. Fractures of the scaphoid: a rational approach to management. *Clin Orthop* 1980;149:90-7.
- Cooney WP III, Dobyns JH, Linscheid RL. Nonunion of the scaphoid: analysis of the results from bone grafting. *J Hand Surg* 1980;5:343-54.
- Herbert TJ, Fisher WE. Management of the fractured scaphoid using a new bone screw. *J Bone Joint Surg [Br]* 1984;66-B:114-23.
- Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33:159-74.
- Leslie IJ, Dickson RA. The fractured carpal scaphoid: natural history and factors influencing outcome. *J Bone Joint Surg [Br]* 1981;63-B:225-30.
- Lindgren E. Some radiological aspects on carpal scaphoid and its fractures. *Acta Chir Scand* 1949;98:538-48.
- London PS. The broken scaphoid bone: the case against pessimism. *J Bone Joint Surg [Br]* 1961;43-B:237-44.
- Maudsley RH, Chen SC. Screw fixation in the management of the fractured carpal scaphoid. *J Bone Joint Surg [Br]* 1972;54-B:432-41.
- Mulder JD. The results of 100 cases of pseudarthrosis in the scaphoid bone treated by the Matti-Russe operation. *J Bone Joint Surg [Br]* 1968;50-B:110-5.
- Russe O. Fracture of the carpal navicular: diagnosis, non-operative treatment, and operative treatment. *J Bone Joint Surg [Am]* 1960;42-A:759-68.
- Stewart MJ. Fractures of the carpal navicular (scaphoid): a report of 436 cases. *J Bone Joint Surg [Am]* 1954;36-A:996-1006.