Reprinted from
ARTHRITIS AND RHEUMATISM
Vol. 33, No. 11, November 1990
© 1990 The American College of Rheumatology
Printed in U.S.A.

THE AMERICAN COLLEGE OF RHEUMATOLOGY CRITERIA FOR THE CLASSIFICATION AND REPORTING OF OSTEOARTHRITIS OF THE HAND

R. ALTMAN, G. ALARCÓN, D. APPELROUTH, D. BLOCH, D. BORENSTEIN, K. BRANDT, C. BROWN, T. D. COOKE, W. DANIEL, R. GRAY, R. GREENWALD, M. HOCHBERG, D. HOWELL, R. IKE, P. KAPILA, D. KAPLAN, W. KOOPMAN, S. LONGLEY, D. J. McSHANE, T. MEDSGER, B. MICHEL, W. MURPHY, T. OSIAL, R. RAMSEY-GOLDMAN, B. ROTHSCHILD, K. STARK, and F. WOLFE

Clinical criteria for the classification of symptomatic idiopathic (primary) osteoarthritis (OA) of the hands were developed from data collected in a multicenter study. Patients with OA were compared with a group of patients who had hand symptoms from other causes, such as rheumatoid arthritis and the spondylarthropathies. Variables from the medical history, physical examination, laboratory tests, and radiographs were analyzed. All patients had pain, aching, or stiffness in the hands. Patients were classified as having clinical OA if on examination there was hard tissue enlargement involving at least 2 of 10 selected joints, swelling of fewer than 3 metacarpophalangeal joints, and hard tissue enlargement of at least 2 distal interphalangeal (DIP) joints. If the patient had fewer than 2 enlarged DIP joints, then deformity of at least 1 of the 10 selected joints was necessary in order to classify the symptoms as being due to OA. The 10 selected joints were the second and third DIP, the second and third proximal interphalangeal, and the trapeziometacarpal (base of the thumb) joints of both hands. Criteria derived using the "classification tree" method were 92% sensitive and 98% specific. The "traditional format" classification method required that at least 3 of these 4 criteria be present to classify a patient as having OA of the hand. The latter sensitivity was 94% and the specificity was 87%. Radiography was of less value than clinical examination in the classification of symptomatic OA of the hands.

To promote uniformity in the reporting of the rheumatic diseases, the Diagnostic and Therapeutic Criteria Committee of the American College of Rheumatology established subcommittees to develop classification criteria. During the last decade, criteria for systemic sclerosis, Reiter's syndrome, systemic lupus erythematosus, rheumatoid arthritis (RA), osteoarthri-

From the American College of Rheumatology Subcommittee on Criteria for Osteoarthritis (Diagnostic and Therapeutic Criteria Committee of the Council on Research).

Supported in part by the ACR and by NIH grant AM-21393 to the Arthritis, Rheumatism, and Aging Medical Information System.

R. Altman, MD: Miami Veterans Administration Medical Center and University of Miami School of Medicine, Miami, FL, and Chair, Subcommittee on Criteria for Osteoarthritis; G. Alarcón, MD: The University of Alabama at Birmingham; D. Appelrouth, MD: Atlanta, GA; D. Bloch, PhD: Stanford University, Stanford, CA; D. Borenstein, MD: George Washington University Medical Center, Washington, DC; K. Brandt, MD: Indiana University School of Medicine, Indianapolis; C. Brown, MD: Rush-Presbyterian–St. Luke's Medical Center, Chicago, IL; T. D. Cooke, MD: Queen's University, Kingston, Ontario, Canada; W. Daniel, MD: The University of Alabama at Birmingham; R. Gray, MD: Springfield, MA; R. Greenwald, MD: Long Island Jewish Medical Center, New Hyde Park, NY; M. Hochberg, MD, MPH: Johns Hopkins University, Baltimore, MD; D. Howell, MD: University of Miami, Miami, FL; R. Ike, MD: University of Michigan, Ann Arbor; P. Kapila, MD: University of Miami, Miami, FL; D. Kaplan, MD: Downstate Medical Center, Brooklyn, NY; W. Koopman, MD: The University of Alabama at Birmingham; S. Longley, MD: University of Florida, Gainesville; D. J. McShane, MD: Stanford University, Stanford, CA; T. Medsger, MD: University of Pittsburgh, Pittsburgh, PA; B. Michel, MD: Rheumaklinik Universitätsspital, Zurich, Switzerland; W. Murphy, MD: Mallinckrodt Institute of Radiology, Washington University, St. Louis, MO; T. Osial, MD: University of Pittsburgh, Pittsburgh, PA; R. Ramsey-Goldman, MD, MPH: University of Pittsburgh, Pittsburgh, PA; B. Rothschild, MD: Arthritis Center of Northeast Ohio, Youngstown; K. Stark, MD: Downstate Medical Center, Brooklyn, NY; F. Wolfe, MD: University of Kansas, Wichita.

Address reprint requests to the American College of Rheumatology, 17 Executive Park Drive NE, Suite 480, Atlanta, GA 30329.

Submitted for publication March 23, 1990; accepted in revised form June 5, 1990.

tis (OA) of the knee, and vasculitis have been published by these subcommittees (1–6). These classification criteria are intended to select the clinical, laboratory, and/or radiographic features which identify patients with a specific disease and to separate these patients from patients with other diseases. Such criteria contain major characteristics of the disease but do not necessarily include the full spectrum of disease manifestations; hence, they are neither appropriate nor intended for use in the diagnosis of an individual patient.

Osteoarthritis is a common clinical syndrome characterized by symptoms related to abnormalities of articular cartilage. There are associated changes in subchondral bone, joint margins, and periarticular structures. Criteria for the classification of OA are intended to separate OA from other conditions and to distinguish clinical OA from the asymptomatic histopathologic OA that is seen on postmortem examination and the asymptomatic radiographic OA that is seen on radiographic examination.

Previously, this subcommittee developed a system that first separated OA into subsets, based upon whether OA is idiopathic (primary) or secondary to some other disease (5). The subcommittee then developed criteria for the classification of OA of the knee, using combinations of 1) clinical, 2) clinical and laboratory, and 3) clinical, laboratory, and radiographic criteria (5). Since OA has different clinical manifestations in different joints of the body, it was thought that the task of criteria development should proceed with one joint area at a time. In this report, the subcommittee has continued its effort by developing classification criteria for symptomatic OA of the hand.

METHODS

Patient selection. Osteoarthritis was classified as described previously (5). Patients with symptomatic and idiopathic OA of the hand (primary OA) were included in the present study. The comparison group consisted of patients without OA but with hand pain caused by articular or nonarticular conditions. Patients with secondary OA of the hands were excluded.

Delphi method. A list of 23 historical, physical, and laboratory features relevant to OA of the hand was composed from a poll of the subcommittee members (7), and the list was then mailed to the subcommittee members. Each feature was rated by each subcommittee member for the following assessments: 1) percentage of patients with OA in whom the feature would be expected (sensitivity), 2) percentage of healthy adults in whom the feature would not be expected (specificity), and 3) percentage of patients with other conditions of the hand (e.g., rheumatoid arthritis, psoriatic arthritis) in whom the feature would be expected (inverse of the specificity). The results were collated and tabulated, listing the mean, standard deviation of the mean, and median for each item (8). As required by the Delphi technique, this list was sent to the subcommittee members, returned, retabulated, and then recirculated to the subcommittee members. Thus, they had the opportunity to revise their initial response on 2 subsequent occasions.

Table 1. Diagnoses of the 199 patients studied

Group, diagnosis	Number of patients
Osteoarthritis patients	100
Generalized	53
Hands only	47
Control patients	99
Rheumatoid arthritis	74
Spondylarthropathies	12
Gout	4
Systemic lupus erythematosus	2
Systemic sclerosis	2
Unclassified polyarthritis	2
Other*	3

* One patient had Darier's disease, 1 had juvenile rheumatoid arthritis, and 1 had diabetic arthropathy.

Prospective study. The list of features from the Delphi procedure was expanded to 51 items regarding history, physical, laboratory, and radiographic findings, and a data collection protocol was designed. Consecutive patients with symptomatic idiopathic OA of the hand or with hand symptoms of other origin were entered prospectively. Patients were evaluated at that visit (index visit) and were not reexamined. Radiographs were interpreted, and the findings were recorded by the participating physician prior to submitting the form and radiographs to the subcommittee. Thirteen centers submitted protocols on patients with hand symptoms (11–25 patients per center), half of whom had symptomatic idiopathic OA of the hand (Table 1).

The clinical diagnosis was the so-called "gold standard" for separating patients into OA and control groups. For this reason, all data forms were reviewed independently by 3 members of the subcommittee (RA, MH, RR-G) to verify the clinical diagnosis. If the reviewers disagreed with the submitted clinical diagnosis, a final diagnosis was negotiated with the center coordinators.

Historical variables included age, sex, race, occupation, symptoms of pain (severity, distribution, frequency), stiffness, hand joint enlargement, occupational trauma, activities of daily living, benefit from antiinflammatory drugs, and symptoms or history of OA at other sites.

Physical examination variables included the distal interphalangeal (DIP) joints, proximal interphalangeal (PIP) joints, metacarpophalangeal (MCP) joints, trapeziometacarpal (base of the thumb, or first carpometacarpal [CMC]) joints, radioscaphoid joints, ulnar styloid–carpal area joints, and the mid-dorsal wrist joints of both hands. All areas were examined for tenderness, soft tissue swelling, hard tissue enlargement, and deformity. Soft tissue swelling of the interphalangeal joints was defined as a "fullness" about the joint as a result of synovial enlargement (9). Hard tissue

Table 2. Selected historical and laboratory features of the study population*

Feature	OA patients (n)	Control patients (n)	Sensitivity (%)	Specificity (%)	P
Age	64 ± 10 (97)	51 ± 15 (97)	–	–	0.001
Age >40 years, %	100	73	100	27	–
Men, %	29 (100)	25 (99)	29	75	0.55
Primary complaint					
Pain, %	45 (76)	46 (90)	–	–	1.0
Reduced function, %	6 (53)	24 (76)	6	76	<0.05
Severe pain, %	5 (99)	20 (99)	5	80	<0.01
Pain frequency, days/month	19 ± 12 (95)	23 ± 11 (99)	–	–	0.003
Hand pain distribution					
DIP joints, %	42 (97)	14 (95)	42	86	<0.001
PIP joints, %	42 (97)	45 (98)	42	55	0.71
First CMC joint, %	37 (97)	15 (95)	37	85	<0.001
MCP joints, %	10 (95)	51 (97)	10	49	<0.001
AM stiffness, hands, minutes	24 ± 32 (95)	82 ± 73 (99)	–	–	<0.001
Impaired ADL, %	58 (99)	81 (97)	58	19	<0.001
Family history of Heberden's nodes, %	39 (98)	17 (99)	39	83	<0.001
Benefit from NSAIDs, %	68 (96)	81 (99)	68	19	0.044
History OA of knees, %	48 (99)	21 (99)	48	79	<0.001
ESR, mm/hour	20 ± 16 (66)	44 ± 29 (89)	–	–	<0.001
ESR <20 mm/hour, %	61	20	61	80	<0.001
RF titer	21 ± 57 (51)	1,088 ± 2,631 (62)	–	–	0.002
RF <1:80, %	86	32	86	68	<0.001

* Unless otherwise indicated, values are the mean ± SD; n values are the number of patients with data entered. OA = osteoarthritis; DIP = distal interphalangeal; PIP = proximal interphalangeal; first CMC = first carpometacarpal (base of thumb); MCP = metacarpophalangeal; ADL = activities of daily living; NSAIDs = nonsteroidal antiinflammatory drugs; ESR = erythrocyte sedimentation rate (Westergren); RF = rheumatoid factor (by latex agglutination).

enlargement of the interphalangeal joints was defined as an increase in the normal structure about the joint as a result of hard tissue or bony enlargement, rather than soft tissue or synovial enlargement. These are the so-called "Heberden's nodes" if the DIP joint is involved and "Bouchard's nodes" if the PIP joint is involved. Deformity of the hand joints was defined as a change in the normal alignment of the joint. In the first CMC joint, this refers to a radial subluxation, giving the base of the thumb a "knobby" or "squared" appearance. Tenosynovitis of the palmar flexors and a qualitative descriptor for reduction in range of motion of each digit were recorded.

Laboratory tests included an erythrocyte sedimentation rate (ESR) (Westergren) and a rheumatoid factor (RF) titer (latex agglutination). Analysis of synovial fluid was requested, but none were submitted.

Findings on hand radiographs, which had been recorded by the center coordinator, were scored independently by 1 of us (WM), a musculoskeletal radiologist, using a format described previously (10). Single-view posteroanterior radiographs of both hands were read blindly by the radiologist, without knowledge of the clinical data. Radiographs were examined (10) for 17 joints in each hand: the 4 DIP joints, 4 PIP joints, the IP joint of the thumb, the 5 MCP joints, the trapeziometacarpal (first CMC) joint, the scaphotrapezoid (first carpal) joint, and the trapeziotrapezoid joint. Each site was examined for the presence of joint space narrowing, osteophytes, erosions (including cystic erosions), and alignment. Each finding was graded on a scale of 0–3, where 0 = normal and 3 = severe or 67–100% abnormal (10). The radiographic interpretations by the center coordinator and by the radiologist were averaged, and this value was used for analysis. An average score of 1 or more was recorded as "present," and an average score of less than 1 was recorded as "absent."

After verification of the diagnosis and interpretation of the radiographs, data were entered into MEDLOG, a data processing program (Information Analysis Corp., Mountain View, CA). Data management and analysis were performed in collaboration with the ARAMIS (Arthritis, Rheumatism, and Aging Medical Information System) staff, based at Stanford University (Stanford, CA).

The accuracy of data entry was verified by the following 2 methods. Twenty percent of the variables entered were randomly selected and reviewed in all records (e.g., diagnosis, age, and RF titer). Twenty percent of the records themselves were completely reentered, and the 2 printed entry charts were compared for errors. Errors were found in 0.6% of the entries.

Data analysis. Variables were included if they had been found to be important in published studies and/or if the Delphi exercise had identified them as discriminating. The data were analyzed by univariate techniques, using *t*-tests for continuous variables and chi-square tests for dichotomous variables. A variable was included in subsequent analyses if it discriminated between OA and control patients at a level of $P < 0.05$.

Using the variables identified by the above method, 2 multivariate techniques were employed to develop classification criteria (11). The first multivariate method employed

Table 3. Frequency of selected physical findings in the hands*

Area, finding	OA patients (n = 100)	Control patients (n = 99)	Sensitivity (%)	Specificity (%)	P
DIP joints (8)					
Tenderness	39	28	39	72	0.11
Soft tissue swelling	8	17	8	83	0.08
Hard tissue enlargement	91	33	91	67	<0.001
Deformity	58	28	58	72	<0.001
PIP joints (10)					
Tenderness	41	66	41	34	<0.001
Soft tissue swelling	22	73	22	27	<0.001
Hard tissue enlargement	81	35	81	65	<0.001
Deformity	44	40	44	60	0.61
MCP joints (10)					
Tenderness	26	72	26	28	<0.001
Soft tissue swelling	11	79	11	21	<0.001
Hard tissue enlargement	32	26	32	74	0.37
Deformity	15	34	15	66	<0.001
First CMC joints (2)					
Tenderness	40	31	40	69	0.20
Soft tissue swelling	15	11	15	89	0.41
Hard tissue enlargement	39	5	39	95	<0.001
Deformity	24	6	24	94	<0.001
10 selected joints					
Tenderness	64	67	64	33	0.69
Soft tissue swelling	30	68	30	32	<0.001
Hard tissue enlargement	96	45	96	55	<0.001
Deformity	66	43	66	57	<0.01

* Values are the percentage with findings in at least 1 joint. Numbers in parentheses are the number of joints examined. The 10 selected joints were the second and third DIP joints, the second and third PIP joints, and the first CMC joints of both hands. See Table 2 for explanations of abbreviations.

the same approach used in classification studies previously published by the American College of Rheumatology (formerly, the American Rheumatism Association) (1–6). This "traditional format" classified a patient as having OA of the hand if a minimum number of criteria were present. The aim was to derive a rule with both high sensitivity and high specificity for separating the OA patients from the non-OA control patients.

The second multivariate method was based on the creation of a classification tree by recursive partitioning (12). With this method, the patients in the sample (including both OA and control patients) are divided into 2 subgroups according to a value of the criterion that "best," or most definitively, separates those with OA from the controls. The "best" variable is determined by a "goodness-of-split" criterion that can be evaluated for any split of any group of the tree. Two subgroups result from every split. The size of the tree is determined by an algorithm which balances tree size with overall classification error.

The sensitivity and specificity rates for the classification rules obtained by either method were thought to be optimistically biased because they applied to the data that were used to make the rule. Less biased estimates of sensitivity and specificity were obtained with the classification tree software program (13) by randomly dividing the sample into parts; for example, a rule obtained for 90% of the sample was tested against the remaining 10%. Sequentially leaving out 10% of the data set allowed 10 rules and 10 tests. The average of the 10 cross-validations yielded an estimate of the accuracy of the classification rule for the classification tree.

Based on a previous study of radiographic progression of OA (10), 10 joints of the hand best showed OA progression: the second and third DIP, the second and third PIP, and the first CMC joints of both hands. These 10 selected joints were grouped by each finding on physical examination and radiography, for criteria development. At least 1 abnormality must have been present for a positive entry unless specified otherwise.

RESULTS

Two hundred twenty-one patients were entered into the study. Review of these medical charts resulted in a change in the diagnostic category for 1 control patient, from a diagnosis of fibromyalgia to OA. Twenty-two patients (10%) were excluded from the analysis: 16 entered as controls had OA concomitant with other conditions (7 entered as RA had secondary OA) and 6 entered as OA had OA plus another rheumatic disease (3 had concomitant gout). Data from the remaining 199 patients were analyzed. There were 100 patients with idiopathic OA of the hands and 99 control patients, 74% of whom had RA (Table 1).

The results of univariate analysis of selected historical features are listed in Table 2 (selected by statistical significance or clinical importance). The

Table 4. Frequency of radiographic findings in the hands*

Area, finding	OA patients (n = 100)	Control patients (n = 99)	Sensitivity (%)	Specificity (%)	P
DIP joints (8)					
Narrowing	78	39	78	61	<0.001
Osteophytes	76	23	76	77	<0.001
Erosions	47	14	47	86	<0.001
Malalignment	46	22	46	78	<0.001
PIP joints (10)					
Narrowing	60	40	60	60	<0.01
Osteophytes	66	24	66	76	<0.001
Erosions	28	35	28	65	0.27
Malalignment	31	25	31	75	0.37
MCP joints (10)					
Narrowing	34	46	34	54	0.07
Osteophytes	31	13	31	87	<0.01
Erosions	13	51	13	49	<0.001
Malalignment	16	32	16	68	<0.01
First CMC joints (2)					
Narrowing	35	24	35	76	0.10
Osteophytes	44	15	44	85	<0.001
Erosions	14	25	14	75	<0.05.
Malalignment	23	15	23	85	0.16
10 selected joints					
Narrowing	75	46	75	54	<0.001
Osteophytes	83	29	83	71	<0.001
Erosions	43	42	43	58	0.94
Malalignment	51	26	51	74	<0.001

* Values are the percentage with findings in at least 1 joint. Numbers in parentheses are the number of joints examined. See Table 3 for the 10 selected joints and Table 2 for explanations of abbreviations.

patients with OA were older than the control patients. Both hands were involved in 96% of all patients. Pain was a component of symptomatic OA of the hand in 90% of the OA patient group and was the primary complaint in 45%. Those OA patients who did not have pain had aching or stiffness (data not shown). Deformity and reduced function were not common presenting complaints in these OA patients (6% and 3%, respectively). Impairment of function was present in over half of the patients with OA (58%), but was less common than in the control group (81%). Injury or occupational trauma was rarely a factor in the hand symptoms of the OA or control subjects in this study group. Nonsteroidal antiinflammatory drugs (NSAIDs) were of benefit in 68% of the OA group and in 81% of the control group. Nearly half (48%) of the OA patient group had a history of concomitant OA of the knees.

The frequency of clinical findings in different groups of joints in both groups of patients is listed in Table 3. One feature common to most of the OA patients was hard tissue enlargement. There was hard tissue enlargement of the second and third PIP joints, particularly in the right hand, and hard tissue enlargement and deformity of the DIP joints. The second DIP joints of the right hand (80%) and left hand (71%) were the most frequently involved.

Selecting individual findings in each joint examined and combining findings in an individual joint (swelling, deformity, etc.) did not separate the OA group from the control group. Findings of lowest frequency in patients with OA were deformity of the MCP joints and soft tissue swelling of the first CMC joint. Palmar tenosynovitis was uncommon in both groups of patients. There were no differences between the OA and control groups in range of motion. Merging bilateral joints (e.g., third DIP of both hands) for individual or combined findings from the joint examination provided no advantage. On examination, the OA group more frequently had OA of the knees (52%) and the lower back (27%) than did the control group (16% and 3%, respectively; $P < 0.001$).

The radiographic changes in the different joint areas are given in Table 4. For individual radiographic findings, comparison of individual joints was neither as sensitive nor as specific as merging findings in rows of joints. Osteophytes were the most sensitive and specific of the radiographic features in individual joint groups (DIP, PIP, first CMC) and in the category of

Table 5. Classification criteria for osteoarthritis of the hand, traditional format*

Hand pain, aching, or stiffness
and
3 or 4 of the following features:
Hard tissue enlargement of 2 or more of 10 selected joints
Hard tissue enlargement of 2 or more DIP joints
Fewer than 3 swollen MCP joints
Deformity of at least 1 of 10 selected joints

* The 10 selected joints are the second and third distal interphalangeal (DIP), the second and third proximal interphalangeal, and the first carpometacarpal joints of both hands. This classification method yields a sensitivity of 94% and a specificity of 87%. MCP = metacarpophalangeal.

"at least 1 of 10 selected joints." Combined radiographic findings for individual joints (i.e., narrowing, osteophytes, and erosion) were more frequent in OA of the second and third DIP joints of each hand separately (79% and 82% in OA patients versus 29% and 36% in controls, respectively). There was less value in combining the features in bilateral second and third DIP joints (84% in OA patients versus 41–44% in controls).

The radiologic interpretations by the center coordinators were compared with those by the radiologist. The interpretation most concordant between the center coordinator and the radiologist was that of osteophytes, particularly of the DIP joints, in the controls and especially in the OA patients. The least concordant interpretation was erosions of the PIP joints in patients with OA.

When the clinical diagnosis from the contributing center and the radiographic diagnosis from the radiologist were compared, there was agreement concerning 155 of the 199 diagnoses (78%). Of the 44 cases in which there was disagreement, 31 radiographs had been interpreted as normal by the radiologist (13 OA patients and 18 controls) and 1 radiograph was of insufficient quality for interpretation by the radiologist. The center coordinator and radiologist concurred on the readings of all the radiographs from patients whose radiographic diagnosis was "normal" according to the radiologist. The radiographic and clinical diagnoses differed in the remaining 12 study subjects (6%): The radiographic diagnosis was OA in 6 patients with RA, 2 with gout, and 1 with Darier's disease; the radiographic diagnosis was RA in 2 patients with OA and 1 with systemic lupus erythematosus.

The traditional format rule for classification of OA of the hand (see Methods) requires that a minimum number of criteria be present in order to classify a patient as having OA. This rule was derived for 30 different combinations of clinical (history, physical, and laboratory) and radiographic criteria. The most sensitive and specific combination is listed in Table 5, and includes the same criteria as those derived from the classification tree described below.

Classification trees were developed for history and physical examination findings (including laboratory test results), radiographic changes, and combinations of the two. The classification tree for the history and physical examination findings was identical to that for the combined history, physical examination, and radiographic features (Figure 1 and Table 6). There were 5 classifying subgroups at 4 levels. In this data set, radiographic criteria were less important than clinical criteria; the contributing centers did enter 13 patients with OA whose radiographic results were normal. The classification tree was 92% sensitive and 98% specific. OA patients misclassified by the tree

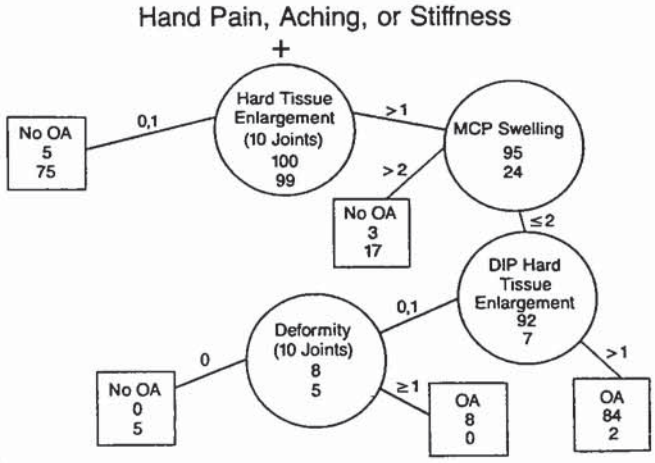

Figure 1. Classification tree for osteoarthritis (OA) of the hand. The tree is derived by recursive partitioning, beginning with the feature of pain, aching, or stiffness, which all study subjects had. The circles show the variables by which the groups are split. The upper number within the circles is the number of patients with OA, and the lower number is the number of patients without OA (from the comparison, or control, patient group). The arms radiating from the circle show the cut-point values on which the variables are split. The boxes show the classifying groups, and specify whether subjects are classified as having OA or not having OA (No OA). The upper number within the boxes is the number of patients with OA, and the lower number is the number without OA; these numbers identify the number of subjects who were properly classified by the criterion as well as the number who were misclassified. For example, the left upper box contains 5 misclassified OA patients and 75 properly classified controls. The classification tree yields an overall sensitivity of 92% and a specificity of 98%. MCP = metacarpophalangeal joint; DIP = distal interphalangeal joint. See Methods for further details.

Table 6. Classification criteria for osteoarthritis of the hand, classification tree format*

1.	Hand pain, aching, or stiffness
	and
2.	Hard tissue enlargement of 2 or more of 10 selected joints
	and
3.	Fewer than 3 swollen MCP joints
	and either
4a.	Hard tissue enlargement of 2 or more DIP joints
	or
4b.	Deformity of 2 or more of 10 selected joints

* The second and third distal interphalangeal (DIP) joints may be counted in both item 2 and item 4a. The 10 selected joints are the second and third DIP, the second and third proximal interphalangeal, and the first carpometacarpal joints of both hands. This classification method yields a sensitivity of 92% and a specificity of 98%. See Figure 1 for graphic depiction of the classification tree.

included those with minimal findings on physical and radiographic examinations (3 patients), swelling of more than 2 MCP joints (3 patients), OA only at the base of 1 thumb (1 patient), and IP joint changes only in the fourth and fifth digits (1 patient). The control patients misclassified as having OA had spondylarthropathies (1 with psoriatic arthritis and 1 with an unspecified type). Cross-validation yielded a sensitivity of 88% and a specificity of 93%.

A classification tree for radiographic changes was derived using 12 classifying subgroups (results not shown). This tree was 85% sensitive and 85% specific, but was very complicated. Osteophytes in at least 2 of the 10 selected joints was the first splitting criterion. As noted, there were 31 normal hand radiographs (13 OA patients and 18 controls; 16%) that were included in the analysis.

The misclassified cases from the classification tree (Figure 1 and Table 6) and from the traditional format classification (Table 5) were compared. The classification tree misclassified 2 more OA cases than did the traditional statistical format, while the traditional statistical format misclassified 11 more controls than did the classification tree. The classification tree properly classified 9 of these 11 by excluding those with more than 3 swollen MCP joints (8 with RA and 1 with gout).

DISCUSSION

Until a "diagnostic test" is available, the clinical diagnosis of symptomatic OA of the hands will depend on the patient's history, physical examination findings, and radiographic features. This study was designed to derive criteria for classifying symptomatic OA of the hand. Classification criteria were derived from a group of patients with OA who were compared with a group of patients with hand symptoms related to rheumatic diseases other than OA. Asymptomatic patients with radiographic evidence of OA, those with secondary OA, and those with both OA and RA were not included in this study because their inclusion would complicate an already difficult task.

In this study, radiographic findings were of less value in classifying OA of the hand than they had been in classifying OA of the knee. The reasons for this are not clear. One possible explanation is the high prevalence of erosions in OA of the hand, a feature which makes it difficult to radiologically distinguish OA from inflammatory arthritides represented in the control group. A second possible explanation is that the single posteroanterior film of the hands (showing only 1 view) may have obscured dorsal or palmar osteophytes.

Findings in a solitary joint or combinations of findings in solitary joints were neither sensitive nor specific for classification of OA of the hand. In contrast, combining rows or groups of joints for single findings was helpful. As found in a prior study of the radiographic progression of OA (10), a combination of 10 selected joints seemed the most useful and efficient for classifying OA subjects, by both the classification tree method and the traditional format (number of criteria present) classification method.

The criteria are the most sensitive and specific when they combine the features of hard tissue enlargement of the DIP and PIP joints with minimal or no swelling of the MCP joints. Hard tissue enlargement involved at least 2 of the 10 selected joints, including at least 2 DIP joints. The 10 selected joints were the second and third DIP, second and third PIP, and first CMC joints of both hands. Soft tissue swelling of the MCP joints must be present in fewer than 3 joints, which tends to exclude patients with active rheumatoid arthritis and diseases in which the MCP joints are similarly inflamed (e.g., spondylarthropathies, hemochromatosis, etc.). If no DIP joint or only 1 of the DIP joints demonstrates hard tissue enlargement, then deformity of at least 1 of the 10 selected joints must be present to classify the condition as OA; thereby, most patients with disease primarily of the first CMC joint are included.

Ehrlich (14) and Campion et al (15) described patients who had OA concomitant with RA in the

hands. Among the patients omitted from our initial analysis were 7 who had concomitant OA and RA. Three of these 7 met the classification tree–derived criteria for OA because of the presence of 0–2 swollen MCP joints. Despite this, we believe the finding of more than 2 swollen MCP joints will reliably identify and exclude most patients with concomitant RA and OA. In this study, elevation of the ESR and the presence of RF were of less value than MCP swelling in differentiating OA patients from controls.

In his memoirs, published posthumously in 1802 (16), Heberden asked, "What are those little hard knobs, about the size of a pea, which are frequently seen upon the fingers, a little below the top, near the joint. They have no connection with the gout, being found in persons who never had it; they continue for life; and being hardly ever attended with pain, or disposed to become sores, are rather unsightly than inconvenient, though they must be some little hindrance to the free use of the fingers." Heberden apparently believed that these changes were not very symptomatic. However, an inflammatory form of OA of the hand was observed by Crain in 23 of his 700 patients with hand OA (17), and the condition is carefully described in an article by Peter et al (18). In a review of 70 patients who had OA of the hand with disabling symptoms that were severe enough to warrant surgery, Swanson and deGroot Swanson (19) reported that these patients experienced the rapid onset of pain, with inflammation and progressive deformity; reduced function was a late event. Our selection criteria are consistent with those used by Acheson et al (20), who found pain and stiffness to be the major complaints in symptomatic OA of the hand. However, our results differ, in that swelling was not a major complaint and repeated trauma did not appear to be associated with OA of the hand in this study population.

Several population surveys have examined the prevalence of hand OA (21–24). These studies utilized a case definition of OA based on the radiographic criteria described by Kellgren and Lawrence (25), which requires the presence of osteophytes. Prevalence studies have not been performed using a clinically derived case definition of hand OA. As was true for OA of the knee, many subjects with radiographic changes will not have pain or other symptoms. Also, some patients with OA have symptoms, but normal findings on radiographs, which suggests that radiographic surveys do not reflect the "true" prevalence of symptomatic OA of the hand. Studies describing radiographic progression (10) or grading (26–28) in OA have not used other rheumatic disease patients for comparison or control purposes.

Standardized guidelines for reading hand radiographs have been published (10,25,26,29,30). These methods seem to have their greatest value in judging the *progression* of disease. In standardizing their method, Kallman et al (26) compared sequential radiographs of men who had no known joint disease at baseline, irrespective of symptoms. It is unknown if their scales would better differentiate OA from other diseases.

In this study, the radiologist was able to separate hand OA from other diseases in 78% of the patients, results similar to those using the classification tree and traditional format for radiographs. However, despite a clinical diagnosis of hand involvement in all 199 study patients, 16% of the hand radiographs were interpreted as normal. This may reflect early disease that is not yet identifiable radiologically. As with the criteria for classification of OA of the knee (5), the case contributors thought that the clinical diagnosis of OA of the hand did not necessarily require the presence of typical radiographic changes. There was a notable discrepancy between the (higher) frequency of bony enlargement on physical examination and the (lower) frequency of osteophytes on the radiograph. This discrepancy can be partly explained by the fact that dorsal or palmar osteophytes may not be detectable on the single posteroanterior radiographic view. Additionally, loss of soft tissue about the joint may appear, on physical examination, to be bony enlargement, and bony enlargement of the proximal and distal sides of the articulation may not have the radiographic appearance of osteophytes.

Univariate analysis demonstrated a significant difference in the ages of the OA and control groups. However, age was probably not a significant contributing factor in separating these groups, since it failed to emerge as a significant feature on multivariate analysis.

It is appreciated that the classification tree method represents a change from the traditional format, and that this application is different and, perhaps, more difficult. It is also appreciated that osteophytes are the only unique radiographic criterion for a diagnosis of OA. However, clinically, Heberden's nodes and hard tissue changes of joints other than the DIP joints appear to be most characteristic of OA of the hand. Simplicity would suggest using the traditional format, utilizing 3 of 4 criteria (Table 5). If both high

sensitivity and high specificity are needed, then the classification tree (Figure 1 and Table 6) is recommended.

This study reinforces the concept that some rheumatic diseases are clinical syndromes. Laboratory and radiographic findings supplement our clinical impressions. Criteria for classification of disease are compilations of clinical signs and symptoms, an imperfect science. Nevertheless, these criteria should facilitate the uniform reporting of OA of the hand in future studies.

REFERENCES

1. Subcommittee for Scleroderma Criteria of the American Rheumatism Association Diagnostic and Therapeutic Criteria Committee: Preliminary criteria for the classification of systemic sclerosis (scleroderma). Arthritis Rheum 23:581–590, 1980
2. Willkens RF, Arnett FC, Bitter T, Calin A, Fisher L, Ford DK, Good AE, Masi AT: Reiter's syndrome: evaluation of preliminary criteria for definite disease. Arthritis Rheum 24:844–849, 1981
3. Tan EM, Cohen AS, Fries JF, Masi AT, McShane DJ, Rothfield NF, Schaller JG, Talal N, Winchester RJ: The 1982 revised criteria for the classification of systemic lupus erythematosus. Arthritis Rheum 25:1271–1277, 1982
4. Arnett FC, Edworthy SM, Bloch DA, McShane DJ, Fries JF, Cooper NS, Healey LA, Kaplan SR, Liang MH, Luthra HS, Medsger TA Jr, Mitchell DM, Neustadt DH, Pinals RS, Schaller JG, Sharp JT, Wilder RL, Hunder GG: The American Rheumatism Association 1987 revised criteria for the classification of rheumatoid arthritis. Arthritis Rheum 31:315–324, 1988
5. Altman R, Asch A, Bloch D, Bole G, Borenstein D, Brandt K, Christy W, Cooke TD, Greenwald R, Hochberg M, Howell D, Kaplan D, Koopman W, Longley S III, Mankin H, McShane DJ, Medsger T Jr, Meenan R, Mikkelsen W, Moskowitz R, Murphy W, Rothschild B, Segal M, Sokoloff L, Wolfe F: Development of criteria for the classification and reporting of osteoarthritis: classification of osteoarthritis of the knee. Arthritis Rheum 29:1039–1049, 1986
6. Hunder GG, Arend WP, Bloch DA, Calabrese LH, Fauci AS, Fries JF, Leavitt RY, Lie JT, Lightfoot RW Jr, Masi AT, McShane DJ, Michel BA, Mills JA, Stevens MB, Wallace SL, Zvaifler NJ: The American College of Rheumatology 1990 criteria for the classification of vasculitis: introduction. Arthritis Rheum 33: 1065–1067, 1990
7. Dalkey NC: A Delphi study of factors affecting the quality of life, The Delphi Method: Techniques and Application. Edited by HA Linstone, M Turoff. Reading, MA, Addison-Wesley, 1975
8. Altman RD, Bloch DA, Bole GG Jr, Brandt KD, Cooke DV, Greenwald RA, Hochberg MC, Howell DS, Kaplan D, Koopman WJ, McShane DJ, Mankin HJ, Medsger TA Jr, Meenan RF, Mikkelsen WM, Moskowitz RW, Murphy WA, Sokoloff L: Development of clinical criteria for osteoarthritis. J Rheumatol 14 [Suppl 14]:3–6, 1987
9. American Rheumatism Association Glossary Committee: Dictionary of the Rheumatic Diseases. Vol. 1: Signs and Symptoms. New York, Contact Associates International Ltd., 1982
10. Altman RD, Fries JF, Bloch DA, Carstens J, Cooke TD, Genant H, Gofton P, Groth H, McShane DJ, Murphy WA, Sharp JT, Spitz P, Williams CA, Wolfe F: Radiographic assessment of progression in osteoarthritis. Arthritis Rheum 30:1214–1225, 1987
11. Bloch DA, Moses LE, Michel BA: Statistical approaches to classification: methods for developing classification and other criteria rules. Arthritis Rheum 33: 1137–1144, 1990
12. Breiman L, Friedman JH, Olshen RA, Stone CJ: Classification and Regression Trees. Belmont, CA, Wadsworth, 1984
13. CART: California Statistical Software. Lafayette, CA, 1984
14. Ehrlich GE: Osteoarthritis beginning with inflammation: definitions and correlations. JAMA 232:157–159, 1975
15. Campion G, Dieppe P, Watt I: Heberden's nodes in osteoarthritis and rheumatoid arthritis. Br Med J 287: 1512, 1983
16. Heberden W: Commentaries. History and Cure of Diseases. Edited by T Payne. London, 1802
17. Crain DC: Interphalangeal osteoarthritis characterized by painful, inflammatory episodes resulting in deformity of the proximal and distal articulations. JAMA 175: 1049–1053, 1961
18. Peter JB, Pearson CM, Marmor L: Erosive osteoarthritis of the hands. Arthritis Rheum 9:365–388, 1966
19. Swanson AB, deGroot Swanson G: Osteoarthritis in the hand. J Hand Surg 8:669–675, 1983
20. Acheson RM, Chan Y-K, Clemett AR: New Haven survey of joint diseases. XII. Distribution and symptoms of osteoarthrosis in the hands with reference to handedness. Ann Rheum Dis 29:275–286, 1970
21. Van Saase JLCM, van Romunde LKJ, Cats A, Vandenbroucke JP, Valkenburg HA: Epidemiology of osteoarthritis: Zoetermeer survey: comparison of radiological osteoarthritis in a Dutch population with that in 10 other populations. Ann Rheum Dis 48:271–280, 1989
22. Butler WJ, Hawthorne VM, Mikkelsen WM, Carman WJ, Bouthillier DL, Lamphiear DE, Kazi IU: Prevalence of radiologically defined osteoarthritis in the finger

and wrist joints of adult residents of Tecumseh, Michigan, 1962–65. J Clin Epidemiol 41:467–473, 1988
23. Lawrence RC, Hochberg MC, Kelsey JL, McDuffie FC, Medsger TA Jr, Felts WR, Shulman LE: Estimates of the prevalence of selected arthritic and musculoskeletal diseases in the United States. J Rheumatol 16:427–441, 1989
24. Brighton SW, de la Harpe AL, van Staden DA: The prevalence of osteoarthritis in a rural African community. Br J Rheumatol 24:321–325, 1985
25. Kellgren JH, Lawrence JS: Radiological assessment of osteoarthritis. Ann Rheum Dis 16:494–501, 1957
26. Kallman DA, Wigley FM, Scott WW Jr, Hochberg MC, Tobin JD: New radiographic grading scales for osteoarthritis of the hand: reliability for determining prevalence and progression. Arthritis Rheum 32:1584–1591, 1989
27. The Epidemiology of Chronic Rheumatism: Atlas of Standard Radiographs. Second edition. Oxford, Blackwell Scientific, 1963
28. Doyle DV, Dieppe PA, Scott J, Huskisson EC: An articular index for the assessment of osteoarthritis. Ann Rheum Dis 40:75–78, 1981
29. Buckland-Wright JC: A new high definition microfocal x-ray unit. Br J Radiol 62:201–208, 1989
30. Buckland-Wright JC, Bradshaw CR: Clinical applications of high definition microfocal radiography. Br J Radiol 62:209–217, 1989