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ABSTRACT

Background Arthropathy is one of the earliest and most common manifestations of hereditary haemochromatosis with a significant impact on quality of life. Although its radiographic features are well known, there is no assessment tool for their evaluation.

Objective To develop and validate a novel scoring system for the evaluation of radiographic features of haemochromatosis arthropathy.

Methods A dichotomous scoring system assessing four radiographic features of haemochromatosis arthropathy and a 4-grade scale reflecting severity of radiographic change have been developed. Standard radiographs (hand, wrist, knee and ankle) of 170 subjects (116 male, 54 female) with genetically confirmed haemochromatosis and laboratory signs of iron overload were assessed by three readers and construct validity, feasibility and cross-sectional reliability (intrareader and inter-reader) were assessed.

Results Intrareader and inter-reader reliability as assessed by percentage pairwise agreement and Cohen's weighed κ were good to excellent for most features and locations evaluated. Radiographic scores correlated well with clinical parameters (bony swollen joint count, hand function and physician's global health assessment; Pearson's correlation, $r^2 = 0.18–0.62$, $p < 0.0001$). A complete set of radiographs took 3.4 ± 1.2 (mean $\pm$ SD) min to be assessed. An atlas of characteristic radiographic features was compiled.

Conclusion A feasible and reliable radiological assessment tool for the evaluation of haemochromatosis arthropathy has been validated and an atlas of characteristic radiographic features provided.

INTRODUCTION

Hereditary haemochromatosis (HH) is the most common inherited disease with an autosomal recessive inheritance causing progressive parenchymal iron overload. Liver fibrosis progressing to cirrhosis and finally to hepatocellular carcinoma and cardiomyopathy are potentially fatal conditions.[1 2] Skin hyperpigmentation, hypogonadism and diabetes mellitus are additional clinical manifestations.[3] Early detection of HH and treatment with phlebotomy can prevent excess morbidity and mortality.[4 5] HH is genetically heterogeneous; however, most patients with clinically overt disease harbour the C282Y homozygous *HFE* (high Fe for iron) gene mutation.[6]

Arthritis is one of the most common and earliest manifestations of HH.[7 8] It was first recognised as a clinical entity distinct from idiopathic osteoarthritis (OA) by Schumacher in 1964.[9] The characteristic affection of the second and third metacarpophalangeal (MCP) joints in haemochromatosis arthritis may help to establish the diagnosis of HH in a precirrhotic stage. Clinically, arthropathy resembles OA and less commonly rheumatoid arthritis.[10] Arthritic presentations with episodes of acute inflammatory arthritis (pseudogout) may be due to calcium pyrophosphate dehydrate (CPPD) crystal deposition to hyaline and fibrocartilage (chondrocalcinosis). Early (before the age of 60 years) identification of chondrocalcinosis should prompt the search for HH by genetic testing.[11] HH still remains an underestimated cause of arthritis, despite the observation that among all other clinical manifestations arthritis has the greatest impact on quality of life and is largely unaffected by phlebotomy.[12]

Radiographic features of primary OA are well defined and a number of validated radiographic scoring systems are in use for the assessment of hand OA.[13–15] There is as yet no validated assessment tool for the evaluation of structural abnormalities in HH arthritis. A precise, objective and reproducible radiological method would be a valuable tool to assess and quantify structural joint damage in patients with HH.

In this study, we established and validated a novel scoring system of radiographic features of haemochromatosis arthropathy in a representative cohort of patients with HH with iron overload. Also, we compiled an atlas of radiographic features to be used as a template and guide for grading of lesions of the hand (MCP joints and wrist) joints and for the identification of chondrocalcinosis in the knee.

METHODS

Study population

Within a period of 3 years (2005–8), subjects with HH were recruited from seven centres for a cross-sectional prospective study on the clinical phenotype of patients with HH and iron overload. The inclusion criteria were serological signs of iron overload with increased transferrin saturation (>55% for men, >45% for women) and either provisional (serum ferritin >300 ng/ml for men and postmenopausal women, >200 ng/ml for premenopausal women) or overt iron overload (serum ferritin >1000 ng/ml or hepatic iron overload on biopsy) independent of the presence of clinical symptoms related to iron overload. Using patient databases

from each centre, we identified eligible subjects. Potential study subjects received a letter inviting them to participate in the study (n=350). Two hundred and nineteen subjects volunteered and were screened, 205 fulfilled the above inclusion criteria. For the present study, recent radiographs of at least one of the assessed joints were required (n=170). All subjects gave written informed consent and the study was approved by the ethics committees of participating institutions.

History taking and clinical assessment

All participants completed a detailed questionnaire including demographic and clinical data. Information on *HFE* genotype, ferritin and transferrin saturation at diagnosis and on previous phlebotomies was retrieved. Blood for confirmatory *HFE* genotyping was drawn. Rheumatic complaints were specifically assessed, including clinical history for joint pain, pattern of joint involvement, duration of symptoms, morning stiffness and clinical status with respect to hand pain and function as well as physician's global health assessment (visual analogue scale). A rheumatologist performed a structured clinical examination including a 48-joint count (shoulders, elbows, wrists, knees, ankles, MCP joints, proximal and distal interphalangeal and metatarsophalangeal joints) for swollen, tender and bony joints. In addition to self-reported measurements, we assessed hand function using Moberg's picking up test, button test and evaluated grip strength with a vigorimeter.[16] Non-rheumatological disease manifestations of haemochromatosis, including liver disease, liver cirrhosis and diabetes, were recorded.

Radiographs

Standard radiographs of hand and wrist, knee and ankle joints were required for this study. Radiographs had to be taken within 6 months of study inclusion. Corresponding radiographs did not have to be on the same film and could vary in size. Radiographs of at least one region of interest had to be available as plain film (n=106, 62.4%) or digitalised (n=64, 37.6%) images and were required to be of sufficient quality to allow interpretation. The following radiographs were available for assessment: anteroposterior and oblique view of hands (n=168, 98.8% of subjects), knee in anteroposterior and lateral view (n=161, 94.7%) and anteroposterior and lateral views of ankle joints (n=164, 96.5%). Four (2.4%), 13 (7.6%) and 153 (90.0%) patients had available radiographs of one, two and all three regions, respectively.

Images for the atlas are derived either from photographic prints, which were in turn photographed, or from electronically stored radiographic images, both from the study cohort. After scoring was completed, images were reviewed and selected to illustrate characteristic individual features of haemochromatosis arthropathy. In order to present grades of arthropathy, they were put in sequence by degree of change. Images were matched for contrast and brightness, cropped to match other images, reversed to face the same direction and saved as uncompressed Tagged Image File Format files.

Readers

Three readers (TD, ES and BM) experienced in the assessment of joint radiographs familiarised themselves with the scoring system. Each reader scored all radiographs separately without knowledge of the patient's clinical data, clinical joint examination and other readers´ scores. Radiographs were assessed once by two readers (ES, BM) and twice by one reader (TD), who read the radiographs for a second time with a minimum interval of 60 days between two readings of the same radiograph. Reading was completed in a 5-month period.

Feasibility

For assessment of method feasibility, 10 complete sets (hands, knees and ankles) of plain radiographs were randomly chosen. Digitalised radiographs were excluded from this assessment to avoid varying picture loading times and user-friendliness of reading-software. Each reader (TD, ES) scored 10 sets of radiographs and completion time was measured with a stopwatch.

Radiographic scoring

Analogue radiographs were read on a vertically positioned light box without the use of a magnifying glass. All radiographs from a patient were read at the same time. Readers entered their assessment onto prepared forms, and the data were then transferred into an electronic database. The development of the radiographic scoring system is outlined in the 'Results' section.

Statistical analysis of data

Descriptive statistics and duration of radiographic assessment were calculated in GraphPad Prism 5.02 and expressed as mean±SD or as median and quartiles if data were unevenly distributed. Differences between means were calculated applying the unpaired t test with Welch's correction if variances were significant. For the determination of construct validity, correlation of the radiographic score with clinical parameters was determined by Pearson's correlation, and r^2 and p values are reported. For all analyses a p value <0.05 was considered significant.

Reliability was determined between readers (inter-reader) and between two readings by the same reader (intrareader). Measures of percentage agreement (pairwise exact agreement) and Cohen's weighed κ were used as measures of reliability. Percentage agreement for each radiographic feature in each type of joint (MCP joint, wrist, knee and ankle) for all three possible pairings of the three readers was calculated in MS Excel. The mean percentage agreement of the three pairings of readers is presented. Percentage agreement is affected by the prevalence of a feature; therefore the weighed κ statistic (calculated in PASW 17.0.2 software), which corrects for chance agreement, was applied to adequately assess reliability.

RESULTS

General characteristics

Demographic and clinical data of 170 included subjects are shown in table 1. According to our inclusion criteria, 104 (61.2%) participants had documented iron overload, while 66 (38.8%) fulfilled criteria for provisional iron overload.

Musculoskeletal symptoms

A complete musculoskeletal examination was performed by a single experienced rheumatologist (table 1). No subject had evidence of other inflammatory rheumatic diseases as judged by clinical, radiological and laboratory studies.

Development of a radiographic scoring system

Based on these clinical observations a radiographic scoring system tailored to detect changes confined to haemochromatosis arthropathy was developed. The second to fifth MCP joints as well as wrist (radiocarpal joint) and ankle (talocrural) joint were scored using the same dichotomous scoring system that covers the presence or absence of four individual radiographic features

Table 1 Clinical characteristics of patients

Patients (N)	170
M/F (N (%))	116 (68.2)/54 (31.8)
Age at inclusion (mean±SD, range) years	55.9±12.3
BMI (mean±SD)	26.6±3.9
Smoking (N (%))	89 (52.4)
Alcohol (N (%))	109 (64.1)
Age at HFE diagnosis (mean±SD) years	49.4±12.1
Ferritin—highest documented (median, quartiles) ng/ml	1254.0 (711.3–2960.2)
Phlebotomy therapy (N (%))	160 (94.1)
Age at start of phlebotomy therapy (mean±SD) years	49.7±11.8
Duration of phlebotomies (median, quartiles) years	4.0 (1.0–8.0)
Estimated number of phlebotomies (median, quartiles)	31 (16–72)
Genotype (N (%))	
C282Y homozygous	152 (89.4)
Compound heterozygous	10 (5.9)
Others*	8 (4.7)
Organ involvement (N (%))	
Aminotransferase elevation	71 (41.8)
Liver fibrosis/cirrhosis	25 (14.7)
Diabetes	23 (13.5)
Cardiomyopathy	19 (11.2)
Rheumatic signs and symptoms—self-reported	
Joint pain (N (%))	127 (74.7)
Age at initial joint complaints (mean±SD) years	45.9±13.2
Duration of joint complaints (mean±SD) years	11.9±11.2
Morning stiffness (N (%))	94 (55.3)
Morning stiffness duration (median, quartiles) min	1.0 (0–10.6)
VAS hand function (median, quartiles)	33.5 (11.0–53.0)
VAS hand pain (median, quartiles)	18.0 (2.0–46.0)
VAS hip pain (median, quartiles)	6.0 (1.0–24.0)
VAS knee pain (median, quartiles)	17.0 (1.8–40.3)
VAS fatigue (median, quartiles)	36.0 (13.0–56.5)
Rheumatic signs and symptoms—physician's assessment	
VAS physician's global health assessment (median, quartiles)	10.0 (0.0–36.0)
Tender joint count ≥1 (N (%))	84 (49.4)
Tender joint count (median, quartiles)	4.3±4.1
Bony swollen joint count ≥1 (N (%))	114 (67.1)
Bony swollen joint count (mean±SD)	11.3±8.4
Swollen joint count ≥1 (N (%))	25 (14.7)
Swollen joint count (mean±SD)	2.8±2.4
Tender MCP2/MCP3 joint count ≥1 (N (%))	24 (14.1)
Tender MCP2/MCP3 joint count (mean±SD)	2.5±1.4
Bony swollen MCP2/MCP3 joint count ≥1 (N (%))	89 (52.4)
Bony swollen MCP2/MCP3 joint count (mean±SD)	3.3±1.4
Swollen MCP2/MCP3 joint count ≥1 (N (%))	16 (9.4)
Swollen MCP2/MCP3 joint count (mean±SD)	2.5±1.0

*C282Y heterozygous three (1.8%), H63D homozygous two (1.2%), juvenile haemochromatosis one (0.6%), t+IVS2+4T/C+IVS2+4T/C one (0.6%), R226W/C282Y one (0.6%).
BMI, body mass index; MCP, metacarpophalangeal; M/F, male/female; VAS, visual analogue scale.

of haemochromatosis arthropathy: joint space narrowing (JSN), erosive changes (erosions and/or subchondral cysts), osteophytes (OP) and chondrocalcinosis. One point was given for the presence of each feature (figure 1). Erosive changes and OP were assessed separately in the proximal and distal compartment of each joint, thus giving a total of six points for a joint with all features present. Chondrocalcinosis was assessed as the presence of calcium deposition in any part of the joint. Each joint was scored separately with a joint score calculated by summing up the respective points. Knee joints were assessed for the presence of chondrocalcinosis only. Semiquantitative assessment of severity of the individual radiographic features was not performed.

Similarly to established radiographic assessment systems of OA,[13] a four-grade scaling system reflecting the severity

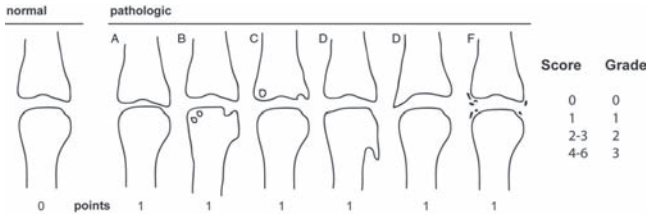

Figure 1 Radiographic scoring system for the assessment of haemochromatosis arthropathy. One point is given for the presence for each of the following four pathological features: (A) joint space narrowing; (B and C) erosion and cyst; (D and E) osteophyte (OP) and (F) chondrocalcinosis. Erosions and OP are assessed separately at the proximal and distal portions of the joint. Severity is assessed by a grading scale derived from the total score of an individual joint, with grade 0 corresponding to 0 points, grade 1 to 1 point, grade 2 to 2–3 points and grade 3 to 3–6 points.

of radiographic changes was derived from scores attributing grade 0 when all of the assessed features were absent, grade 1 for 1 point, grade 2 for 2–3 points and grade 3 for 3–6 points (figure 1). Cumulative radiographic scores that included left-sided and right-sided joints were calculated in patients with respective radiographs available as follows: total radiographic score (MCP joints, wrist and ankle joints; maximum 72 points), hand score (MCP joints, wrist joints; maximum 60 points) and MCP2/MCP3 score for all second and third MCP joints (maximum 24 points). These were used as a surrogate marker for haemochromatosis arthropathy in further analyses.

Feasibility

The mean time (±SD) required to perform the evaluation of a complete set of radiographs was 3.4±1.2 min and was mainly dependent on the severity of radiographic changes.

Reliability

Internal reliability for each individual feature in each type of joint was assessed as inter-reader and intrareader variability. Mean percentage agreement and mean Cohen's weighed κ for the three possible pairings of three readers are presented as measures of reliability (table 2). Inter-reader reliability on proximal and distal OP, JSN and proximal erosions in MCP joints was good.[17] Reliability was lower for distal erosions and chondrocalcinosis in MCP joints. Chondrocalcinosis was assessed reliably in knee and wrist joints. Inter-reader reliability was less strong but sufficient for all features in the wrist. In the ankle, reliability was sufficient only for OP and low for all other features. In intrareader reliability testing, the reader was able to substantially reproduce his own readings with κ ranging from 0.35 (erosion/cyst distally in MCP joints) to 0.87 (chondrocalcinosis in knee and wrist joints). Intra-reader reliability was higher than inter-reader reliability for most features.

Construct validity

To demonstrate construct validity the cumulative MCP2/MCP3 score, the hand score and the total score were compared with clinical parameters of patient-reported rheumatic symptoms (hand function), clinical findings at the second and third MCP joints (MCP2/MCP3 bony joint count) as well as all joints (total bony joint count), respectively, and the physician's global health assessment (figure 2). Excellent correlation for both, the MCP2/MCP3 and the total radiographic score (all scored joints), with the number of bony second and third MCP joints (r^2=0.51, p<0.0001) and the total bony joint count (r^2=0.48, p<0.0001)

was found. Also, hand function was significantly correlated with the hand score (r^2=0.18, p<0.0001). The best correlation was seen between the total radiographic score and physician's global health assessment (r^2=0.62, p<0.0001).

Radiographic atlas

An atlas of characteristic radiographic features of haemochromatosis arthropathy showing the various stages of arthropathy in MCP and wrist joints according to our grading system is presented in figure 3. In addition to scored joints, knee radiographs were assessed for the presence of chondrocalcinosis, only. Various types of chondrocalcinosis without reference to grading are depicted in (figure 4).

DISCUSSION

HH is one of the most common inherited diseases and arthropathy is the most frequent complication, reducing quality of life. Severity of arthropathy can be measured by standard tools that evaluate objective clinical findings, effects on the quality of life, functional impairment and disability as perceived by patients. Radiographic evaluation complements these diagnostic tools by enabling assessment of structural changes and eliminating the drawbacks of subjective perception of pain and function by patients. Although there are no direct comparison studies with primary hand OA, haemochromatosis arthropathy may present with a different distribution and prevalence of radiographic characteristics and thus requires a radiological assessment tool tailored to reflect these features.

To our knowledge, this is the first study to validate a scoring system for the evaluation of radiographic features of haemochromatosis arthropathy in a representative cohort of patients with HH. The scoring system was designed to account for selected radiographic changes, the character, combination and localisation of which can be considered characteristic for haemochromatosis arthropathy.[10 18 19] To simplify the scoring system and improve reliability, we opted for a dichotomous model in contrast to other scores such as the Kellgren–Lawrence score. Using such a scoring system could underestimate severe articular disease (eg, severe JSN but no OP formation in a single patient). However, preliminary data from our cohort suggest a very good correlation between our score and the Kellgren–Lawrence score (r=0.89), which will be part of a follow-up study. To emphasise the importance of destructive and proliferative changes, proximal and distal portions of joints were scored separately. Only joints that are known to be typically affected in haemochromatosis were evaluated,[20] and the scoring system was not applied to joints in which haemochromatosis arthropathy appears identical to OA (hip and knee).

Radiographic scores compared well with clinical parameters and established measures of functional disability and clinical findings, thus proving the construct validity of our scoring system. Radiographic scores correlated well with MCP joint involvement and physician's global health assessment. The weaker correlation with self-assessed hand function may be explained by additional joint involvement such as the interphalangeal and carpometacarpal joints, the latter being especially important for hand function.[21] Interestingly, we could not observe a correlation of joint

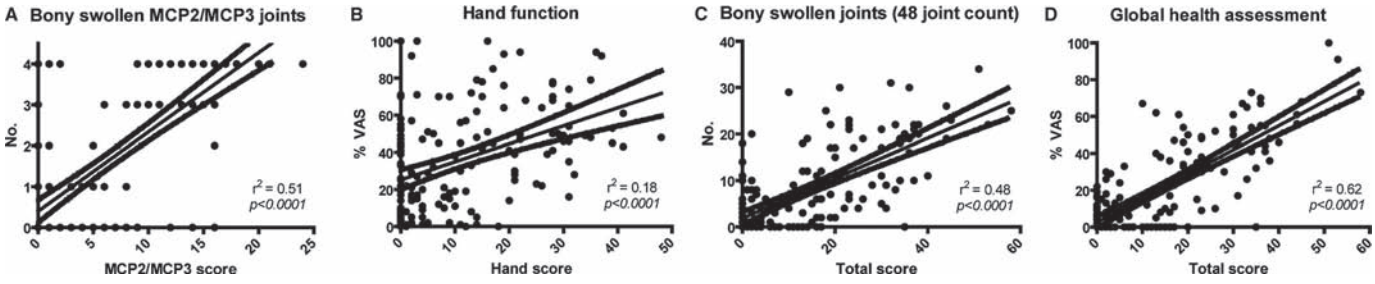

Figure 2 Correlation of radiographic scores with self-reported complaints: (A) radiographic metacarpophalangeal (MCP) 2/MCP3 joint score versus bony swollen second and third MCP joint count; (B) radiographic hand score versus hand function (visual analogue scale); (C) radiographic total score versus total bony swollen joint count; (D) radiographic total score versus physician's global health assessment.

Table 2 Reliability testing; agreement is expressed as the mean percentage agreement of inter-reader agreements achieved by three readers (TD vs BM, ES vs BM, TD vs ES) or a single intrareader agreement between readings of TD at two different occasions

Joint		MCP		Wrist		Knee		Ankle	
N radiographs		168		167		161		164	
N joints (left+right)		1344		334		322		328	
Feature	**Agreement**	**Inter-reader**	**Intrareader**	**Inter-reader**	**Intrareader**	**Inter-reader**	**Intrareader**	**Inter-reader**	**Intrareader**
JSN	%	87.1	88.5	73.1	82.6	–	–	82.7	89.3
	κ	0.70	0.75	0.44	0.65	–	–	0.37	0.64
Erosion/cyst proximally	%	87.7	90.4	91.0	87.7	–	–	87.2	85.7
	κ	0.60	0.74	0.50	0.55	–	–	0.31	0.57
Erosion/cyst distally	%	93.3	85.9	86.4	82.0	–	–	91.9	90.2
	κ	0.33	0.35	0.49	0.52	–	–	0.39	0.55
OP proximally	%	88.4	93.8	86.6	86.8	–	–	73.9	84.2
	κ	0.72	0.84	0.43	0.52	–	–	0.41	0.67
OP distally	%	86.3	91.1	89.2	84.7	–	–	84.3	88.1
	κ	0.63	0.75	0.47	0.40	–	–	0.44	0.65
Calcinosis	%	98.1	98.4	92.0	96.7	91.9	96.6	95.3	98.2
	κ	0.20	0.48	0.60	0.87	0.71	0.87	0.29	0.74

Similarly, the mean of Cohen's weighed κ is shown.
JSN, joint space narrowing; MCP, metacarpophalangeal joints; OP, osteophyte.

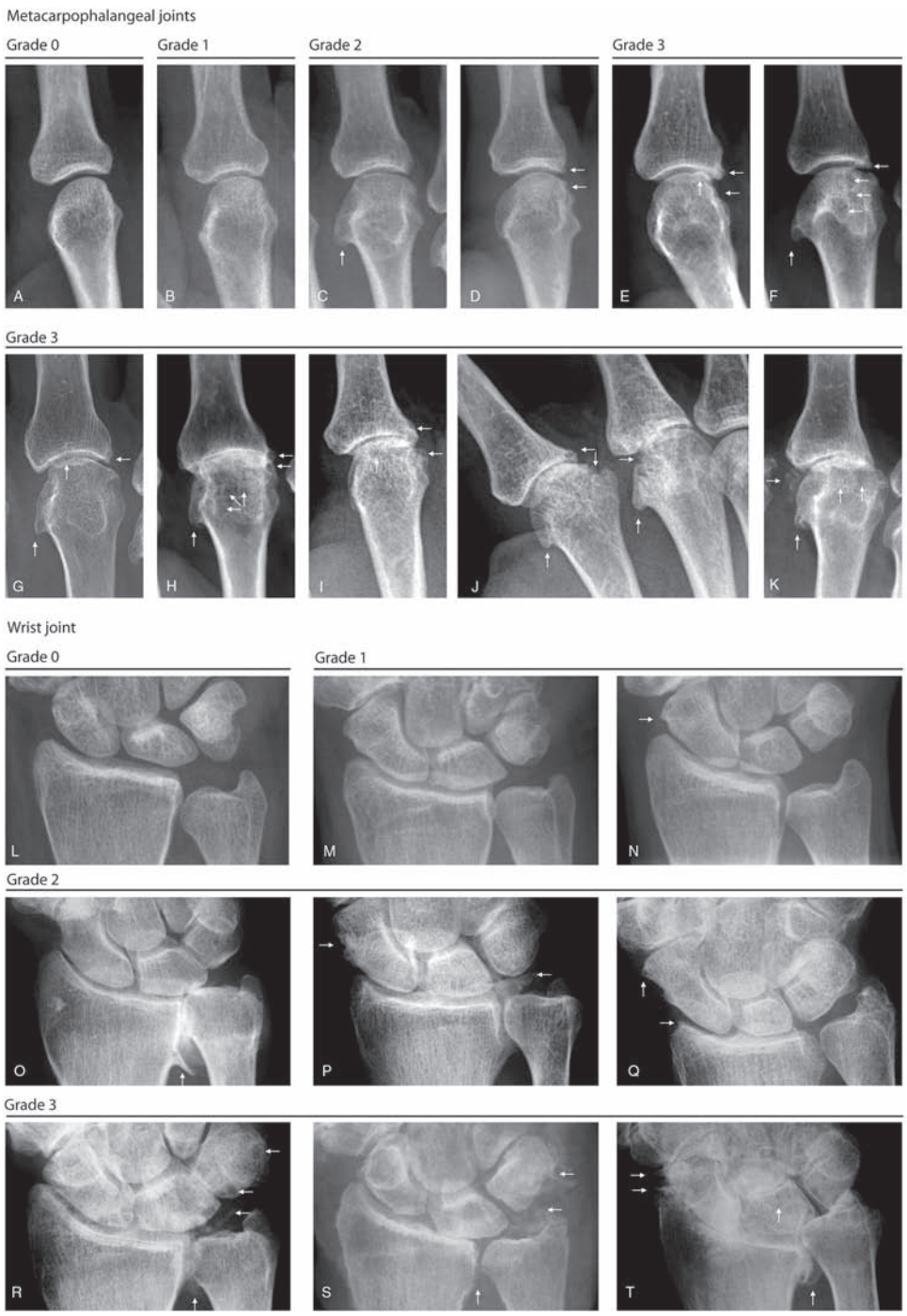

Figure 3 Characteristic radiographic features of haemochromatosis arthropathy in the metacarpophalangeal (MCP) (A–K) and wrist joints (L–T). Anteroposterior view radiographs are assembled in order of increasing severity of changes with corresponding grading shown. MCP joints: grade 0: (A) no pathological changes; grade 1: (B) joint space narrowing (JSN); grade 2: (C) JSN and osteophyte (OP) proximally; (D) JSN, erosion proximally and small OP distally; grade 3: (E) JSN, OP proximally and distally, erosion proximally; (F) JSN, large beak-like OP proximally, small OP distally, cystic lesions proximally; (G) JSN, large beak-like OP proximally, small OP distally, erosions proximally; (H) complete joint destruction with severe JSN, OP proximally and distally, cysts proximally and distally; (I) complete joint destruction with OP proximally and erosion proximally and distally; (J) lateral view of MCP2 and MCP3 joints with proximal OP and severe erosive changes and proximal cystic lesions (MCP3 joint); (K) complete joint destruction with and obliterated joint space, characteristic beak-like OP and cystic lesions proximally and chondrocalcinosis. Wrist joint: grade 0: (L) no pathological changes; grade 1: (M) JSN; (N) OP distally; grade 2: (O) JSN and OP proximally; (P) JSN, OP proximally and erosions distally; (Q) JSN, erosion/cyst distally, OP proximally; grade 3: (R) JSN, OP proximally, cysts distally and chondrocalcinosis; (S) JSN, OP proximally and distally and chondrocalcinosis; (T) complete destruction of wrist joint with obliteration of the joint space, OP proximally and distally and cystic lesions distally.

scores with organ involvement (data not shown). Investigators could assess a complete set of radiographs within 4 min, and thus the evaluation was easy to use. Standard radiographs and a light box are the only technical requirements, the method thus being readily available without additional cost.

The method was reliable as different readers could substantially reproduce each other's scores. The mean percentage agreement between pairs of readers ranged from 73.1% (JSN in wrist joints) to 98.1% (chondrocalcinosis in MCP joints). Using Cohen's κ,[17] good to excellent inter-reader and

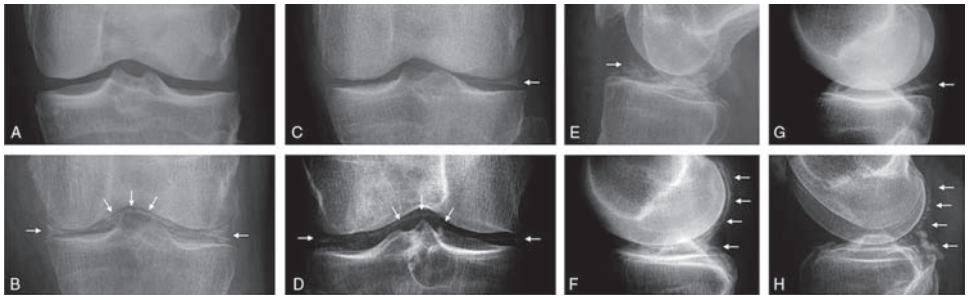

Figure 4 Chondrocalcinosis of the knee joint in anteroposterior (A–D) and lateral (E–H) radiographs. (A) No chondrocalcinosis; (B–E) chondrocalcinosis of articular soft tissue; (F–H) chondrocalcinosis of knee cartilage.

intrareader reliability was achieved for the assessment of JSN, presence of proximal erosive changes and OP in MCP joints. Assessment of all features in the wrist joint was satisfactory to good. Chondrocalcinosis was reliably rated at characteristic sites (wrist and knee) with good reliability, whereas reliability in ankle and MCP joints was low. This difference may be due to misinterpretations of discrete opacities in MCP joints and the frequent finding of JSN and deformities that interfere with identification of CPPD deposits in the ankle. In the ankle, only OP were rated reliably and agreement was low for JSN, erosions/cysts and chondrocalcinosis. Thus we were unable to demonstrate sufficient reliability in the assessment of the ankle joint and recommend the use of the scoring system for the evaluation of MCP and wrist joints, only. Also, our data confirm, in agreement with others,[15] that evaluation of erosions/cysts and chondrocalcinosis in sites other than the knee and wrist is difficult. The discrepancy between high percentage agreement and low κ values in some features can be explained by the large number of negative findings of these features in the cohort.

We present a scoring system that will provide clinicians with an objective tool for the assessment of haemochromatosis arthropathy of MCP and wrist joints and will be useful for the determination of disease severity. It may help to describe haemochromatosis arthropathy and quantify joint damage in clinical studies. Sensitivity to change of our scoring system should be evaluated in a further study with follow-up radiographs, to validate the scoring system for the use in prospective follow-up and thus for the evaluation of disease progression or, if applicable, effects of treatments. To assist implementation of the scoring system, we compiled an atlas of standard radiographic findings of haemochromatosis arthropathy. It can be used as a guide in the evaluation of individual features and staging of haemochromatosis arthropathy of MCP and wrist joints and may serve as a reference for training.

The prevalence of chondrocalcinosis in the general population in the age group 65–75 years is 10–15%.[22] In our cohort, we found punctate and linear radio-dense areas in fibrocartilage and hyaline cartilage in 33.5% of patients. Chondrocalcinosis is detected in type II polyarticular OA, which resembles haemochromatosis arthropathy, but not in type I polyarticular OA.[23] Our data thus confirm the fact that HH promotes CPPD crystal deposition. The most common localisation of chondrocalcinosis was, in agreement with others,[24] in the knee joint (19.4%) as compared with MCP (8.2%), wrist (15.0%) and ankle joints (8.8%) and was assessed reliably (κ>0.7). The combined assessment of all four joint regions led to an increased sensitivity of detection. Therefore we included this important aspect of haemochromatosis arthropathy in the presented atlas.

In summary, we have designed a scoring system for the assessment of specific radiographic features of haemochromatosis arthropathy. We have shown that it is a feasible, valid, easy-to-use and reliable tool for assessment of the degree of MCP and wrist joint involvement in HH and can serve as a complement to physicians' assessment and for clinical studies.

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Competing interests None.

Ethics approval This study was conducted with the approval of the ethics committees of the participating institutions: University Hospital Vienna, University Hospital Erlangen.

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