Review Article
Conventional radiography in rheumatoid arthritis: new scientific insights and practical application

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Abstract: Rheumatoid arthritis (RA) is a chronic systemic disease of unknown origin that predominantly involves synovial tissue. RA affects 0.5% of the global population, with a clear predilection for women. Conventional radiography (plain radiographs or X-rays) is the most widely used imaging technique for diagnosing and monitoring the progression of RA. Advanced imaging techniques (e.g. magnetic resonance imaging, computed tomography, ultrasound, and nuclear scintigraphy), that are better suited for detecting soft-tissue inflammation are available, but they are more costly and some of them may expose the patient to higher doses of radiation. Plain film radiographs are inexpensive, easy to generate, can be compared with baseline and prospective films, and provide a permanent, reproducible record. The plain radiographs of the hands and feet can detect the features that are specific to RA such as joint space narrowing or erosions, and serial radiography can be used as a objective marker for monitoring treatment response in clinical trials. This review discusses the use of conventional radiography for diagnosing and detecting early structural changes in joints and providing a historical overview of commonly used methods of scoring radiographs in RA.

Keywords: Rheumatoid arthritis, conventional radiography, scoring methods, joint space narrowing, erosions, disease progression

Introduction

Rheumatoid arthritis (RA) is a chronic autoimmune joint inflammatory disease that if not treated or poorly controlled by therapy can lead to anatomical lesions and deformation of the joint through erosive changes to the cartilage and the subchondral bone [1]. The prevalence of the disease in Italy is about of 0.5%, with a clear predilection for women (male/female ratio 1:3) [2]. In daily clinical practice and in studies, structural damage in RA is assessed by the presence of bone erosions on conventional radiography. Although nowadays various advanced diagnostic imaging techniques, such as magnetic resonance imaging (MRI), computed tomography (CT), ultrasound (US), and nuclear imaging are at the disposal of the physicians, conventional radiography remains the imaging modality of choice and, therefore, is essential in evaluating the efficacy of experimental treatments [3, 4].

The presence of radiographic bone erosions is fundamental for the classification of RA, according to both the American College of Rheumatology (ACR) 1987 [5] and the ACR/European League against Rheumatism (EULAR) 2010 classification criteria [6]. The definition of erosive disease (‘typical erosions’) to be applied to 2010 ACR/EULAR criteria is when erosions are seen at least in three separate joints at any of the following sites: the proximal interphalangeal (PIP) joints, the metacarpophalangeal (MCP) joints, the wrist (counted as one joint) or the metatarsophalangeal (MTP) joints on radiographs of both hands and feet [7].

Many researches have shown that, joint damage occurs within the first 2 years after symptoms appearance [8]. Other authors have demonstrated how early versus delayed treatment is associated with better clinical and structural outcomes, emphasizing the precocity of structural damage [9, 10]. With the increasing use of
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Disease-modifying antirheumatic drugs (DMARDs) and biological agents (bDMARDs), early diagnosis is now of paramount importance and disease progression has to be assessed regularly to monitor efficacy of the treatment [11, 15]. These points were outlined in European recommendations and models for management of early arthritis, and prognostic markers for persistent arthritis have been established [11, 16, 17].

Common radiographic features in RA

Radiographic lesions in RA include soft tissue swelling, juxta-articular osteopenia, bone erosions, joint space narrowing (indicative of loss of cartilage), cysts, joint subluxations, malalignment, and ankylosis [18].

The first radiographic changes observed in RA are soft tissue swelling and periarticular osteopenia. Bone density is reduced adjacent to the joint as a result of local synovial inflammation. Thus, the bone may appear less dense (a darker shade on the radiograph) around the articular surfaces. However periarticular osteopenia is not a specific radiographic sign of RA and can occur in other conditions [19].

The inflamed synovium slowly invades adjacent structures causing damage and destruction to the cartilage. This aggressive process leads to joint space narrowing and bone erosions that can be seen on radiographs. It is important to underline that X-ray imaging provides only limited information on soft tissue lesions. US or MRI are the modalities of choice to visualise these structures and provide useful and objective informations on pathological changes such as synovitis and tenosynovitis [4].

The joint space narrowing in RA tends to be uniform and concentric, reflecting the generalised nature of the synovial inflammation within the joint. This kind of damage may be the most important predictor of irreversible physical disability and work impairment [20].

The erosions in RA tend to be periarticular and are often described as marginal erosions as they are close to the joint and reflect the direct

Figure 1. Marginal erosion in rheumatoid arthritis. The patient is a 37-year-old female with symptoms compatible with rheumatoid arthritis for six months. X-ray showing characteristics of erosive rheumatoid arthritis in its early stage: well-defined marginal erosion in the second metacarpophalangeal joint. The joint space is preserved, and neither deformity nor changes in bone alignment are observed.

Figure 2. Rheumatoid arthritis involving the wrist. The patient is a 56-year-old female with rheumatoid arthritis for 8 years. Plain radiograph, posteroanterior view of the right wrist showing gross erosions in the tip of the ulnar styloid process, marked osteoporosis in the neighboring medullary bone, and thickening of adjacent soft tissues.
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mechanical action of the hypertrophied synovium and granulation tissue (Figure 1). Marginal erosions are the typical radiographic manifestation of the disease and are part of the classification criteria of RA [6]. These lesions primarily concern the “bare areas” in the periphery of joints and have to be searched for in both hands and feet. The hands are involved symmetrically. Usually, the second and third MCP and the third PIP are the first joints damaged. Distal interphalangeal (DIP) joints involvement without proximal involvement is rare.

The wrist joint is commonly affected in RA, has proved to be more sensitive to changes in bone erosions than other joint areas, and bone changes have been shown to possess a predictive value with respect to further radiographic erosive progression [21-23]. In a longitudinal study of wrist, radiographic erosions of the styloid ulnar were seen as a relatively early isolated finding in 25% of the patients. Moreover, the distal radioulnar joint showed a rapid increase of erosions and was involved in 78% of the patients with established disease [21] (Figure 2). In the feet, changes are most commonly seen in the MTP and PIP joints [24, 25]. Erosive damage in feet x-ray can appear before hand involvement becomes clear. All MTP joints could be involved and the fifth MTP joint has been recognized as an area of early joint damage [25-27] (Figure 3).

Fusion or joint ankylosis characterize the later stages of RA. Fusion usually takes place in deformed or malaligned position (Figure 4). These alterations strongly reduce the functionality of hands and feet with a great impact on the activities of daily living. In the late stages, extensive erosions may be combined resulting in resorption and tapering of the ends of the bones.

The cervical spine is also a common target of RA, ranking only third after the hands and feet in the frequency of involvement [18, 28-30]. The proportion of RA patients who experience cervical spine involvement at some point of their disease has ranged from 14% to 88% [28, 29, 31, 32]. Inflammatory activity in the cervical spine begins early and progresses clinically and radiologically in tandem with the peripheral joint involvement. In fact, the severity of the peripheral erosive damage is strongly correlated with the degree of structural damage in the cervical spine. The atlas-axis - first and second cervical vertebrae (C1 and C2) - articulation is

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Figure 3. Rheumatoid arthritis involving the metatarsophalangeal and interphalangeal joints. Radiograph of the both feet shows concentric joint space narrowing in all the metatarsophalangeal joints. Erosions are seen in the first, fourth and fifth metatarsophalangeal joints, which are deformed to some extent, and in the first interphalangeal joints.

Figure 4. Advanced rheumatoid arthritis. Radiograph of the hand shows severe joint space narrowing of the radiocarpal, intercarpal, carpometacarpal, metacarpophalangeal, and interphalangeal joints. There is also subluxation and deviation of the fingers.
one of the chief disease target. The erosive pannus formation at this site often leads to bony destruction and laxity in the surrounding ligamentous complex, especially the transverse. The subsequent loss or malfunction of anchoring structures results in atlantoaxial subluxation (AAS) [33] that is the most common abnormality at the cervical spine, with a prevalence of 5-75% [29, 34-36]. The subluxation can be anterior, posterior, lateral, and vertical. The anterior atlantoaxial subluxation (aAAS) is the most common subtype with a reported prevalence ranges from 10% to 55% [33, 35, 37-40]. A distance of the anterior odontoid peg (dens) from the anterior ring of atlas (anterior atlanto-dental interval-AADI) ranging from 2.5 mm to 5 mm has been considered pathological [41-43]. AADI values greater than 9 mm may indicate severe cervical spine involvement [36, 44]. Posterior AAS is less frequent and usually caused by fracture of the dens [44]. A posterior atlantodental interval smaller than 14 mm was used as a sensitive marker for spinal cord compression [45]. Lateral AAS has been reported in 10-20% of patients [46-48]. This kind of subluxation is considered when lateral masses of C1 are displaced laterally more than 2 mm in comparison with C2. They can lead to head tilt and rotation deformities [49]. Another form of subluxation is the vertical subluxation of the axis (VS), also known as atlantoaxial impaction, cranial settling, superior migration of the odontoid, or pseudobasilar invagination. It is secondary to the destruction of occipitoatlantal and atlantoaxial joints and surrounding soft tissues [49]. The methods used to highlight vertical subluxation include McGregor’s line, MacRae’s line, Chamberlain’s line, Ranawat’s method, Redlund Johnell’s method, and Kauppie Sakaguchi’s method [50-52].

Conventional radiography remains the first-line investigation of choice for detecting cervical spine subluxations. There is general agreement that dynamic views are extremely valuable, most notably for detecting aAAS, which may be present only when the neck is flexed [32, 53] (Figure 5). CT reconstructions in the coronal and sagittal planes supply a precise assessment of the C1-C2 complex, thereby ensuring the detection of lateral and vertical AAS [30]. MRI with a range of sections offers the most comprehensive evaluation of rheumatoid lesions. Furthermore, MRI is the only method capable of visualizing a clinically silent C1 e C2 pannus and of providing a detailed assessment of effects on neurological structures [29, 31, 54, 55].
### Table 1. Major advantages and disadvantages of conventional radiography in rheumatoid arthritis

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Conventional radiography</td>
<td>Ionizing radiation</td>
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<tr>
<td>Wide availability and easy access</td>
<td>Relative insensitivity to early bone damage</td>
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<tr>
<td>Low cost</td>
<td>Insufficient to assess soft tissues</td>
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<tr>
<td>Images easily understood by clinicians</td>
<td>Pitfalls due to over-impression of three-dimensional structures on two-dimensional image</td>
</tr>
<tr>
<td>Standardization available</td>
<td>Technical variables (accurate joint placement, proper exposure, and reproducibility of films)</td>
</tr>
<tr>
<td>Valid assessment methods</td>
<td>Interpretational variables (reader training, inconsistencies in interpretation of radiographic change)</td>
</tr>
<tr>
<td>Good reproducibility</td>
<td>Pathophysiological variables (lag time of radiographic change behind pathological change)</td>
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<tr>
<td>High specificity for bone changes (differential diagnostic work-up)</td>
<td></td>
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<tr>
<td>American College of Rheumatology classification criteria of rheumatoid arthritis</td>
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</table>

### Table 3. A comparison of common radiographic scoring methods used in rheumatoid arthritis

<table>
<thead>
<tr>
<th>Type of scoring method</th>
<th>Van der Heijde modification of the Sharp method</th>
<th>Genant modification of the Sharp method</th>
<th>Larsen method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description of scoring system</strong></td>
<td>Erosion is assessed in 16 joints for each hand and wrist, and six joints for each foot. One point is scored if erosions are discrete, rising to 2, 3, 4, or 5 depending on the amount of surface area affected. JSN is scored as follows: 0 = normal; 1 = focal or doubtful; 2 = generalised, less than 50% of the original joint space; 3 = generalised, more than 50% of the original joint space or subluxation; 4 = bony ankylosis or complete luxation.</td>
<td>Erosion is scored according to an eight point scale with 0.5 increments, where 0 = normal; 0+ = questionable or subtle change; 1 = mild; 1+ = mild worse; 2 = moderate; 2+ = moderate worse; 3 = severe; and 3+ = severe worse. JSN is scored according to a nine point scale with 0.5 increments, where 0 = normal; 0+ = questionable or subtle change; 1 = mild; 1+ = mild worse; 2 = moderate; 2+ = moderate worse; 3 = severe; 3+ = severe worse; and 4 = ankylosis or dislocation.</td>
<td>It differentiates six stages from 0 (normal) to 5, reflecting progressive deterioration, and provides an overall measure of joint damage. The grading scale ranges from 0 to 5: 0 = intact bony outlines and normal joint space; 1 = erosion less than 1 mm in diameter or JSN; 2 = one or several small erosions (diameter more than 1 mm); 3 = marked erosions; 4 = severe erosions (usually no joint space left and the original bony outlines are only partly preserved); and 5 = mutilating changes (the original bony outlines have been destroyed).</td>
</tr>
<tr>
<td><strong>Advantages and disadvantages</strong></td>
<td>Sensitive for detection of radiographic progression, but requires training and is time consuming to apply.</td>
<td>Sensitive, but presents difficulties in assessing progression of structural damage. Requires training to apply efficiently.</td>
<td>Semiquantitative global method, easier to learn and to use, less sensitive to changes than the modified Sharp methods.</td>
</tr>
</tbody>
</table>
Advantages and disadvantages of plain radiography

The main utilities of plain radiographs include low costs, wide availability, standardization of validated assessment methods, and good reproducibility [56]. Moreover, thanks to its high specificity, conventional radiography is advantageous for differential diagnosis, easily revealing the features that are specific for each disorder.

By contrast, the disadvantages are well recognized, involving exposure to ionized radiation and insufficient assessment of the synovium or other soft-tissue structures, which can be critical in making diagnostic or therapeutic decisions (Table 1).

Some studies have reported that plain radiography has poor sensitivity in detecting bone erosions compared with MRI [23, 57-59]. We also found that plain radiography has very poor sensitivity (22%) in detecting bone erosions in RA wrist joints, compared with CT [60]. The wrist is one of the most difficult joint of the body to assess radiographically [61]. Difficulties of conventional radiography for a detailed evaluation of wrist are due to several factors, such as the complex anatomy of the wrist, the irregularities of the bone margins (e.g., at level of ligaments attachment) and the presence of nutritive foramina that can appear like erosions. These aspects make arduous the discrimination between the normal anatomy and the erosions [61]. For that reason, CT can be considered the standard reference method for the detection of erosive bone destructions in early stage of the disease [62, 63] (Figure 6). Current generation of ultrafast CTs allow to acquire high resolution volumetric data in few seconds and providing detailed anatomical informations. Moreover, 3D volume rendering techniques make feasible to generate high quality images, offering a realistic anatomical view from tomographic data (Figure 7).
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Additional limitations of conventional radiography are the following: (a) technical variables, (b) interpretational variables, and (c) pathophysiological variables (Table 1).

Radiographic progression as an outcome measure in RA

Progression of structural damage to joints is commonly used as an outcome measure in RA and in observational studies. Reasons are that radiographs of hands and feet can be easily performed, that valid scoring methods are available, that inflammatory activity in the joints leads to radiographic progression, and that radiographic damage correlates with physical function [64]. Inflammation of the joints may fluctuate over time in individual patients, and radiographic damage may be considered a reflection of joint inflammation over time [65].

Numerous studies have documented the course and prognostic factors associated with progression of radiographic joint damage in RA [66-70]. These studies clearly show that the rate of progression of joint damage correlates strongly with disease duration and disease activity. In a cohort of active early RA patients, Knijff-Dutmer et al [71] found a linear relationship between time integrated disease activity parameters and progression of radiographic damage. Similar results were reported by Molenaar et al [72] and Welsing et al [73]. Our prospective analysis has confirmed that higher cumulative disease activity is associated with a higher radiological progression in early RA [65].

The hypothesis that chronic inflammation and joint destruction are closely linked is further supported by data from imaging studies. Some works demonstrated that, in early RA, bone damage occurs proportionately to the degree of synovitis, but not in its absence [72, 74, 75].

Destructive joint damage judged on conventional radiography occurs within the first years of RA [76, 77] and early detection of erosions is closely related to a poor long-term clinical outcome [78-80]. Radiological outcome studies have shown that 70-75% of patients with recent-onset RA develop bony erosions within the first 2-3 years [8, 81]. Furthermore, we showed that within 3 months of disease onset, 34.9% of 481 patients have erosions evident on X-ray [82]. Similarly, in the ESPOR cohort study (a French cohort of early arthritis), 20% of 813 patients with a mean disease duration of 107 days had hand or foot erosions [83].

The joint damage at baseline is a significant predictor of progression [65, 78, 84-86]. Two long-term studies [87, 88] found that the independent predictive variable of radiographic damage was baseline radiographic score.

Joint damage increases slowly over the course of RA [77], and disability decreases during the first years with disease control and worsens with disease duration [17, 81, 89]. In early RA, functional impairment is believed to be particularly due to inflammatory processes as measured by disease activity [65]. In long-term

Table 2. Features of rheumatoid arthritis included in the different radiographic scoring methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Erosion</th>
<th>Joint space narrowing</th>
<th>Osteoporosis</th>
<th>Soft tissue swelling</th>
<th>(Sub) luxation</th>
<th>Ankylosis</th>
<th>Cyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steinbrocker (1949)</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Kellgren (1956)</td>
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<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>Sharp (1971)</td>
<td>+</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>Larsen (1977)</td>
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<tr>
<td>Sharp (1985)</td>
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<td>-</td>
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<tr>
<td>Genant (1998)</td>
<td>+</td>
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<td>-</td>
<td>+</td>
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<td>-</td>
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<tr>
<td>van der Heijde/Sharp (1989)</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Larsen (1995)</td>
<td>+</td>
<td>+</td>
<td>-</td>
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<tr>
<td>Rau/Larsen (1995)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
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<tr>
<td>Ratingen (1998)</td>
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<td>-</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>SENS (1999)</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>SES (2000)</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
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</table>

SENS = Simple Erosion Narrowing Score; SES = Short Erosion Scale; + Included in the scoring system; - Not included in the scoring system.
established RA, disability may be mainly relat-
ed to joint damage [80, 90]. A significant corre-
lational between the changes in x-ray scores and
the subsequent disability status has been con-
fi

mmed [64]. Thus, as recommended by EULAR
[11], the changes in X-ray scores/progression
should be evaluated in clinical practice to bet-
ter monitor individual patients with early RA so
that decisions to change therapeutic strategies
and prevent further disease progression can be
taken as early as possible.

Radiographic scoring methods

There are numerous radiographic methods to
evaluate progressive joint damage in RA that
continue to be an important end-point in trials
assessing medication efficacy and in following
response to treatment. Some give a global
assessment for the whole patient [91, 92],
whereas others score specific joint abnormali-

ties [93, 94] (Table 2). Radiographic scores,
such as the Sharp scores and their modifi-
cation [95, 96], are the standard methods for
determining joint damage and its progression
[65, 97].

The first attempt to standardize the assess-
ment of radiographic damage in RA was made
with the Steinbrocker method [91]. In this
method, global damage score in the hands and
wrists was graded as follows: stage I-oste-
oporosis may exist, no erosions; stage II-os-
teoporosis, slight cartilage or subchondral bone
destruction may be present; stage III-oste-
oporosis, cartilage and bone destruction; and
stage IV-same as III, with bony ankylosis. This
method had several limitations and is no longer
used.

The Kellgren scoring method was similar to the
Steinbrocker method: a global grade was given
as the summation of abnormalities for all the
joints in both the hands and wrists [92]. Osteoporosis and erosions were recorded sep-

erately and graded as follows: none (0), doubt-
ful (1), slight (2), moderate (3), and severe (4).
The atlas of standard reference included films
of the hands, wrists, forefoot, and cervical spine [94].

In 1971, Sharp et al proposed a scoring method
for the hands and wrists that includes two
scores, one for erosions and the other for joint
space narrowing (JSN) [98]. Twenty nine areas
in each hand and wrist are scored for erosions,
and 27 for JSN. Counts for erosion range from
0 to 5, to give an erosion score between 0 and
290. Counts for JSN range from 0 to 4, to give a
score between 0 and 216. The number and
selection of joints in the Sharp method evolved
in the years, and a modification proposed in 1985
of the Sharp method [99] is now considered the
standard for the method. It considers 17 areas
for erosion: five PIP joints, five MCP joints, 1st
metacarpal base (MCB), multangular as one
unit, navicular, lunate, triquetrum (and pis-
iform), radius, ulnar bone for each hand and
wrist; and 18 areas for JSN: five PIP, five MCP,
carpometacarpal (CMC) 3 to 5, multangular-
navicular, lunate-triquetrum, capitate-navicular-
lunate, radiocarpal, radioulnar joints for
each hand and wrist. Each erosion scores one
point, with a maximum of five points for each
area. Erosion scores range from 0 to 170. One
point is scored for focal joint narrowing, two
points for diffuse narrowing of less than 50% of
the original space, and three points if the reduc-
tion is more than half of the original joint space.
Ankylosis is scored as four. The score for JSN
ranges from 0 to 144. Another modification
was devised by Genant et al [100]. The Genant
modification of the Sharp method focuses on
14 sites for erosions and 13 sites for joint
space narrowing (JSN): erosion is scored
according to an eight point scale with 0.5 incre-
ments, where 0 = normal; 0+ = questionable or
subtle change; 1 = mild; 1+ = mild worse; 2 =
moderate; 2+ = moderate worse; 3 = severe;
and 3+ = severe worse. In each hand, IP of the
thumb, PIP, MCP, 1st CMC, scaphoid, ulna, and
radius are included. The score for erosion for
both hands ranges from 0 to 98. JSN is scored
according to a nine point scale with 0.5 incre-
ments, where 0 = normal; 0+ = questionable or
subtle change; 1 = mild; 1+ = mild worse; 2 =
moderate; 2+ = moderate worse; 3 = severe;
3+ = severe worse; and 4 = ankylosis or dislo-
cation. In each hand, IP of the thumb, PIP, MCP,
CMC 3 to 5, capitate-scaphoid-lunate, and the
radiocarpal joint are included (Table 3). The
score for JSN for both hands ranges from 0 to
104. The total erosion score and the total joint
score are each normalised based on a maxi-
mum score of 100, and these two normalised
scores are added to give a joint total score in
which erosions and JSN are evenly weighted.

In the final van der Heijde modification of the
Sharp method [101], erosions are assessed in
16 joints (five MCP, four PIP, IP of the thumbs,
Table 3

1st MCB, radius and ulna bones, trapezium and trapezoid as one unit (multangular), navicular, lunate) for each hand and wrist, and six joints (five MTP, IP) for each foot. One point is scored if erosions are discrete, rising to 2, 3, 4, or 5 depending on the amount of surface area affected (complete collapse of the bone is scored as 5). The score for erosion ranges from 0 to 160 in the hands and from 0 to 120 in the feet (the maximum erosion score for a joint in the foot is 10). JSN is evaluated in 15 joints (five MCP, four PIP, CMC 3 to 5, multangular navicular-lunate, radiocarpal) for each hand and wrist, and six joints (five MTP, IP) for each foot. JSN is combined with a score for (sub)luxation and scored as follows: 0 = normal; 1 = focal or doubtful; 2 = generalised, less than 50% of the original joint space; 3 = generalised, more than 50% of the original joint space or subluxation; 4 = bony ankylosis or complete luxation. The score for JSN ranges from 0 to 120 in the hands and from 0 to 48 in the feet. Therefore, the total van der Heijde radiographic score ranges from 0 to 448 [96] (Table 3).

In 1974, Larsen developed a method based on a set of standard films. It differentiates six stages from 0 (normal) to 5, reflecting progressive deterioration, and provides an overall measure of joint damage. The Larsen original method has also been modified several times by the author. In the 1977 version [102, 103], the six stages are the following: grade 0 = normal; grade 1 = slight abnormalities (periarticular soft tissue swelling and periarticular osteoporosis and slight JSN); grade 2 = definite early abnormalities; grade 3 = medium destructive abnormalities; grade 4 = severe definite abnormalities; and grade 5 = mutilating abnormalities. The wrist is considered as one unit and the score is multiplied by five. Joints assessed include five DIP, four PIP, five MCP, the wrist as one unit for each hand and wrist, and 10 MTP; two IP for the feet. The score ranges from 0 to 250 (Table 2). In 1995, Larsen revised a method to evaluate radiographs in long term studies [104]. The main differences from the original are deletion of scores for the thumbs and 1st MTP; subdivision of the wrist into four quadrants (the joints considered are PIP 2 to 5 and MCP 2 to 5 in each hand, four quadrants in the wrist, and MTP 2 to 5 in each foot); deletion of soft tissue swelling and osteoporosis; distinction between erosions of different sizes. The grading scale ranges from 0 to 5: 0 = intact bony outlines and normal joint space; 1 = erosion less than 1 mm in diameter or JSN; 2 = one or several small erosions (diameter more than 1 mm); 3 = marked erosions; 4 = severe erosions (usually no joint space left and the original bony outlines are only partly preserved); and 5 = mutilating changes (the original bony outlines have been destroyed) (Table 3). The score ranges from 0 to 160.

In 1995, Rau and Herborn proposed a modification of the Larsen method [105]. Thirty two joints are evaluated: eight PIP, two IP of the thumbs, 10 MCP, two wrists, and 10 MTP. The six stages are defined as follows: 0 = normal; 1 = soft tissue swelling and/or joint space narrowing/subchondral osteoporosis; 2 = erosions with destruction of the joint surface (DJS) 25%; 3 = DJS 26-50%; 4 = DJS 51-75%; 5 = DJS >75%. The score ranges from 0 to 160.

Few years later Rau et al developed a new method derived from the Larsen score including a quantitative appraisal of the percentage of loss of the joint surface. This method is known as a “Ratingen score” [106]. The score examines the following joints or areas: 10 PIP, 10 MCP, four sites in the wrist (navicular, lunate, radius, and ulna), eight MTP (2 to 5), and two IP on the great toe. This new method restricts scoring of an individual joint to definite changes of erosion and joint destruction. The extension of the erosion into the bone is not considered. The amount of joint surface destruction is defined by the length of the clearly visible interruption of the cortical plate in relation to the total joint surface. Grades are then assigned in this way: grade 1 = one or several definite erosions totalling destruction of <20% of the total surface; grade 2 = joint surface destruction 21-40%; grade 3 = 41-60%; grade 4 = 61-80%; grade 5>80%. Adding the scores from 38 areas gives a total score ranging from 0 to 190.

Table 3 summarizes the principal characteristics of the three common radiographic scoring methods used in RA.

An important disadvantage of the scoring methods for clinical trials is the fact that they require significant training, and that scoring according to these methods is very time consuming, making these techniques unfeasible for routine clinical practice. The scoring time is one drawback of both Sharp method and Sharp/van der Heijde method, related to their detailed evaluation [107, 108].
In order to overcome these limitations, it has been developed the Simplified Erosion and Narrowing Score (called “SENS”), that is entirely based on the van der Heijde modification of the Sharp score [107] and the Short Erosion Scale (SES), a change of the Larsen method [109]. The SENS was developed by van der Heijde and is a simplified method by summing the number of eroded and narrowed joints on selected joints on hand and foot radiographs [107]. It exploits the same joints of hands and feet, but as opposed to applying a semiquantitative scale of 0-4 for joint space narrowing and 0-5 for erosions, the SENS simply dichotomizes (bimodal answer modality) whether an erosion is absent (score of 0) or present (score of 1), and whether joint space narrowing is absent (score of 0) or present (score of 1) [107]. The hand score per joint can, therefore, range from 0 to 2. Joint erosions are scored in 32 joints in the hands and wrists and 12 joints in the feet. JSN is scored in 30 joints in the hands and wrists and in 12 joints in the feet. Consequently, the maximum total erosion score is 44, the maximum total JSN score is 42 and the maximum total score is 86 (Figure 8) [107]. The SENS showed a good intra- and inter-reader reliability, and is sensitive to change [110].

The SES considers 12 joints: three of four regions of the wrist as defined by Larsen (medial-proximal, medial-distal, and lateral-proximal) and MCP 2, 3, and 5 [109]. Each joint is graded as in the 1995 Larsen system [104].

However, despite considerable effort to either reduce or at least define the intrinsic limitations of radiographic scores, problems remain with reader variability, floor and ceiling effects [56, 93, 111] and an inability to accurately quantify damage and its progression, particularly in the wrist.

Conclusions

Plain radiography remains the gold standard for the assessment of structural joint damage in RA even though this may not necessarily be the most sensitive imaging investigation in this setting [3]. It is generally safe, accessible and cost effective with the opportunity to provide timely and useful information which is helpful to a range of health professionals. Characteristic X-ray findings are part of the ACR/EULAR classification criteria for RA [5, 6], can be helpful in the differentiation of RA from other joint conditions, and can serve as an outcome parameter in clinical trials that investigate the potential of new drugs to preserve structural integrity of the joints. Appropriate scoring methods are designed to semiquantitatively measure radiographically visible changes, especially erosive destruction and-in part-cartilage loss. These methods are well validated, reproducible, and yield similar results in clinical trials.

Disclosure of conflict of interest

None.
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References


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[107] Van der Heijde D, Dankert T, Nieman F, Rau R and Boers M. Reliability and sensitivity to


