The RoentgenCoach–Rheumatology—a novel tool to enhance efficacy of radiological scoring of rheumatoid arthritis

Results of experimental scoring of 72 cases

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Rheumatoid arthritis is a systemic inflammatory disease with predominant involvement of major and minor joints of the appendicular skeleton (Bohndorf and Imhof 1998, Peloschek 2000). Despite a high degree of individual variability concerning the course of this disease, distinct patterns of anatomic distribution and severity of morphologic changes have been described and a great number of radiological scoring (quantification) methods have been deducted from these observations (Peloschek 2000).

The multi-disciplinary approach to the diagnosis (qualification) of arthritic entities is supported by imaging methods displaying synovitis with magnetic resonance imaging (MRI) or Power-Doppler-Ultrasound (PD-US) (Kainberger et al. 1996, Imhof et al. 2000). Conventional radiography is insensitive to these early changes but provides a possibility to observe progression of bony changes (Larsen 1977, 1995). The astonishing amount of information achieved by MRI raises new theoretical and practical problems which are to be solved (Østergaard et al. 1999, Rand et al. 1999, Boers 2000).

Among different scoring systems, Larsen's scoring method, and its modification by Scott is used predominantly in Europe whereas in North America the method developed by Sharp and its modifications by Genant and van der Heijde are more popular (Larsen et al. 1977, 1987, Scott et al. 1995, Sharp 1996, Genant et al. 1998, van der Heijde 1999, Rau et al.1995). Recently Rau published a new approach to the radiological quantification of RA (Ratingen – Score)(Rau et al. 1998).

Despite extensive research activities, all scoring modalities show inherent drawbacks: First of all, the technique of positioning hands and feet varies, which is the main cause of imprecision. Secondly, observer-dependent variabilities occur due to the reader's varying familiarity with the disease and scoring method. Thirdly, there is no satisfactory comparability between the results of different methods and modifications. Finally, in order to be used in clinical settings, the process of scoring should be applied with high feasibility. The major limitation of all methods is, however, their limited precision and accuracy despite their tedious procedure (Wassenberg et al. 1998, Wolfe et al. 1998, Peloschek 2000).

A computer assistance to achieve highest evidence possible for radiological quantification of hands and feet of rheumatic patients in dedicated settings was developed. To provide a systematic access to quantitative imaging of RA a comprehensive tutorial was created.

The approach is to see radiological quantification of arthritic lesions as a process-oriented pattern. The first step in this process has to be the

indication, followed by an investigation and interpretation leading to a diagnosis. The radiological diagnosis has to be communicated to the referring physician (rheumatologist), who will come to a definite clinical diagnosis respecting results of other examinations (e.g. laboratory measures and physical examination). Subsequently a radiological quantification may be indicated.

Radiological quantification

Indication

The Austrian Guidelines Catalogue for optimal use of clinical imaging methods was established to assist clinicians to find the most suitable imaging approach for the single case. This consensus guideline serves as basis for an online information system (www.vbdo.at or www.oerg.at). The development of the RoentgenCoach-Rheumatology can be seen as an implementation of the guideline's indication for a radiological quantification of RA. According to this concept, the referral diagnosis has to be the definite clinical diagnosis of RA. This is of greatest importance because in case of clinically suspected RA other imaging modalities (e.g. Power-Doppler-Ultrasound or MRI) are indicated!

Investigation

To achieve highest reproducibility application of an optimized and standardized investigation programme is required (Peloschek 2000, Wicke 1983, Zimmer-Brossy et al. 1995). This is extensively presented in the online Tutorial (www.univie.ac.at/radio/radio.htm). The personnel (assistants and radiologists) dealing with quantitative radiography has to be informed about possible sources of inaccuracy. Assistants have to be trained in proper positioning of hands and feet in the center beam, which is probably the most critical part of an investigation. It is on the liability of a radiologist to monitor image quality applying the specially adapted image quality parameters very consequently.

Interpretation

The quantitative interpretation of these radiographs requires bone radiologists or other experienced observers, who are familiar with the sophisticated radiological anatomy and pathology of the appendicular skeleton. The principles of interpreting radiographs for the quantification of RA are explained in the Tutorial and a selection of recommended literature can be used to build up a more profound knowledge.

Diagnosis and documentation

In this case, in which the definite clinical diagnosis is a precondition for scoring, the documentation focuses on the quantification and progression of disease. The interdisciplinary communication of a diagnosis is often complicated by different points of view of individual specialists. The more comprehensive and complete the communication is, the higher the effect of an investigation.

The RoentgenCoach–Rheumatology

Compared with conventional scoring modalities, a computer assisted access offers following advantages: structured data input and analysis lowering variance by standardization, superior learning curve because of a dedicated help program (Tutorial), fast access via Internet, faster and more precise calculations of sum scores and indices, possibility of cross-calculation to other scores, and reliable documentation of results in suitably designed printout. With data stored in a database, long-term follow-up of a patient is facilitated. The software is programmed as a fully operative Java stand-alone application software in an open way allowing gradual implementation of new modules (Kainberger 1999).

More precise data analysis and computation of scores is a crucial part of a quality control program and offers potential to reform present scoring methods. The RoentgenCoach–Rheumatology supports Larsen's or Rau's scoring approach.

The tutorial

The tutorial was initiated to explain basic pathology and radiology of rheumatoid arthritis, principles of non-biased scoring, the importance of optimized and standardized radiographic projection technique and proper use of the Larsen- and Rau-Score. It is programmed to allow an easy access via Internet.

The data input sheet

Care was taken to follow the radiologist's approach in analyzing. In a first step quality of films has to be assessed with respect to brightness, contrast, spatial resolution, artefacts, and positioning of limbs. In a second step, film reading is performed by clicking with the mouse on a graph on the monitor. To combine scoring with routine reporting, pre-memorised standard formulations can be added and corrected with personal comments.

The compute sheet

Alternatively Larsen's or Rau's score is calculated and may be compared with the score of previous studies. The graphical layout is designed to give an overview on former scores and an access to further possibilities (calculate, export, print, send).

The report

The semi-automated documentation by the RoentgenCoach–Rheumatology includes the following data: Overall score and progression, separate score and progression for each hand and foot, separate score and progression for every joint, image quality.

The qualitative diagnosis as a prerequisite for the quantitative diagnosis is not listed separately, but additional diagnostic comments can be added. The layout of the report can be designed individually.

Methods

In a first pre-clinical study the software was tested in an unstructured fashion by 42 radiologists and rheumatologists with various degree of experience in the field of rheumatologic imaging. Participants used the software to score selected cases with their opinions recorded in a questionnaire. After reading these questionaires and following our own observations we started to develop and implement new features and optimized some of the existing for a next evaluation. For this structured evaluation we selected 10 fully documented cases of RA, blinded them, and four radiologists scored hands and feet. Two of them used the RoentgenCoach-Rheumatology and two of them used preformatted paper-sheets. After another statistical analysis of achieved data and evaluation of personal observations the software was further improved for the next evaluation of another 20 selected cases read by the same four radiologists. The time needed for quantification, excluding calculation and documentation was taken.

Table 1. Mean (range) time savings using the Roentgen-Coach-Rheumatology, minutes

	Without the Roentgen-Coach	With the Roentgen-Coach
Experienced bone radiologists	7.4 (4.8–9.5)	5.2 (4.8–6.1)
Resident radiologist	8.1 (5.1–12.3)	7.6 (6.8–8.3)

Note: The time needed for calculation and documentation is excluded.

Results

Compared to conventional scoring modalities, a computer-assisted access offers following advantages:

Quality control of films: Film reading with the RoentgenCoach-Rheumatology can only be performed after assessment of the quality of exposure with respect to brightness, contrast, spatial resolution, artefacts, and positioning of limbs. It was shown that different exposure geometry (e.g. positioning of limbs on the film cassette) performed in individual radiological settings lead a systematic error. Availability of the program via Internet should provide common access for quality control in multi-centre studies. The study confirms the lack of a standard for positioning of limbs.

Structured data analysis and input: In analogy to clinical practice of film reading, data input follows anatomic localisation, qualification and quantification of radiographic signs, and differential diagnosis. For all readers, clicking with a mouse on a graph of the data input screen, speeded up the procedure; altogether scoring without computer assistance needed median 16 (9–30)% more time (Table 1; Peloschek et al. 2000). Time for calculation and documentation, performed semi-automatically by the RoentgenCoach-Rheumatology, is excluded.

Concerning the interreader variability there was no significant influence by the software. No data loss occurred.

Calculation of data: Sum scores and optional indices are calculated and stored in a database. Human miscalculations are avoided. Export to statistical software was easily possible.

Reporting: Documentation of results in a specifically designed printout improves communication between radiologists and rheumatologists. Additionally the possibilities of direct export to other programmes (statistics, data-base) and electronic distribution obviously alleviate and accelerate scientific work. Also long-term follow-up of a patient is facilitated and the overall procedure is quicker.

Discussion

Quality control, as in other fields of medical imaging, seems to be a crucial part of diagnosing RA. Because of the cumbersome process of scoring dozens of joints of hands and feet of an individual patient, scoring is still only accepted for research purposes. General acceptance by radiologists will be increased by providing assistance through the Tutorial www.univie.ac.at/radio/radio.htm. The precise knowledge about the time needed to score a patient will help to reduce prejudices against this tedious procedure.

Scoring of RA should not only be applied for research purposes but also for assessing the individual clinical follow-up. Also the possibilities to print out the report immediately and the possible combination of scoring and routine reporting by pre-memorised standard formulations corrected with personal comments seem to alleviate the procedure.

Post-processing and calculation of data has to be improved. A potential improvement could be the semi-automated calculation of indices recommended in recent literature, furthermore the possibility of cross-calculations between different scoring systems. An important feature of a computerized scoring system may be the structured way of data input. Lowering of inter- and intra-observer variance is a crucial part of scoring but a systematic approach increases length of film reading. The main advantage of this computerised access is to shorten the time of data input but not to improve precision and accuracy. The data shows that only experienced readers are capable of scoring arthritic lesions sufficiently.

Attempts have been made to extend the application from a simple scoring programme to a rheumatologic expert system. In this respect, the inherent goal of computerized analysis of radiographs to be used as "second opinion" by the radiologist should be met. In this means further efforts to develop tools for automated image analysis will be made.

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