InterCriteria Analysis of Behterev's kinesitherapy program

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Abstract: Ankylosing spondylitis refers to the group of seronegative spondyloarthropathies – diseases of the spine and peripheral joints that progress to immobilization and there is no rheumatoid factor found in the blood. In this paper, we have used experimental results of Behterev's Disease Analysis. We make the consequent step in a series of research, aimed at proposing the application of the novel approach of InterCriteria Analysis (ICA) to medical data, aimed at the discovery of correlations between important healthy indicators, based on available medical data.
Keywords: InterCriteria Analysis, Bechterev's Disease, Rheumatoid spondylitis, Ankylosing spondylitis.
AMS Classification: 03E72.

1 Introduction

Ankylosing spondylitis (spondyloarthritis) is a chronic inflammatory disease of the axial skeleton that leads to partial or even complete fusion and rigidity of the spine. Males are disproportionately affected and upwards of 90% of patients are positive for the HLA-B27 genotype, which predisposes to the disease. The most characteristic early finding is pain and stiffness in the neck and lower back, caused by inflammation of the vertebral column and the sacroiliac joints. There is tendency to ossification and ankylosing, shown on Figure 1. The pain typically improves with activity and is especially prominent at night. Other articular findings include tenderness to percussion and displacement of the sacroiliac joints (Mennell's sign), as well as limited spine mobility, which can progress to restrictive pulmonary disease. The most common extra-articular manifestation is acute, unilateral anterior uveitis. Diagnosis is primarily based on symptoms and x-ray of the sacroiliac joints, with HLA-B27 testing and MRI reserved for inconclusive cases. There is no curative treatment, but regular physiotherapy can slow progression of the disease. Additionally, NSAIDs and/or tumour necrosis factor-α inhibitors may improve symptoms. In severe cases, surgery may be considered to improve quality of life.[18].
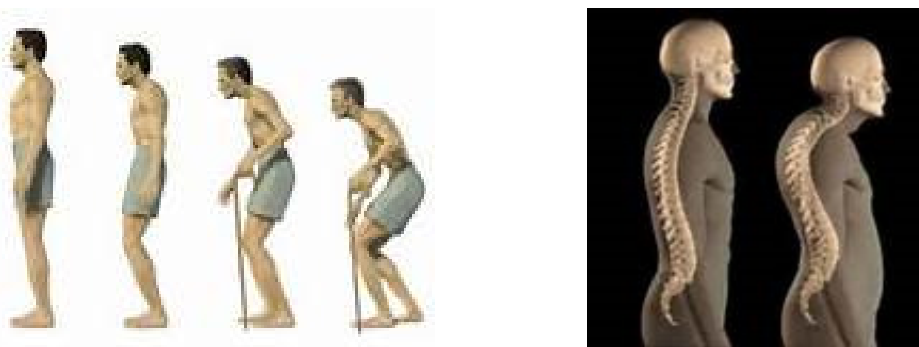

Figure 1. Progression of the disease

Diagnostic approach:
- Physical examination, patient history, and pelvic x-ray: If results are conclusive, no additional testing is required!
- If inconclusive → HLA-B27 testing
- If still inconclusive → pelvic MRI.

Clinical test:
- Chest expansion measurement: in full expiration and inspiration
- Pathological difference: < 2 cm
- Physiological difference: > 5 cm
- Spine mobility tests
- Examination of the hip [11]
- Mennell sign: tenderness to percussion and pain on displacement of the sacroiliac joints [15].
- FABER test: FABER (Flexion, ABduction, and External Rotation) provoke pain in the ipsilateral hip.

Laboratory findings:

- ↑ CRP and ESR
- Auto-antibodies (e.g., rheumatoid factor, antinuclear antibodies) are negative
- HLA-B27 positive in 90–95% of cases
- However, < 5% of HLA-B27 positive individuals have ankylosing spondylitis.

Symptoms of the disease:

Most common presenting symptoms: back and neck pain
- Gradual onset of dull pain that progresses slowly
- Morning stiffness that improves with activity
- Pain is independent of positioning, also appears at night
- Tenderness over the sacroiliac joints
- Limited mobility of the spine (especially reduced forward lumbar flexion)
- Inflammatory enthesitis (e.g., of the Achilles tendon, iliac crests, tibial tuberosities): painful on palpation
- Ductility's
- Arthritis outside the spine: hip, shoulder, and knee joint [9].

Extra-articular manifestations:

- Most common: acute, unilateral anterior uveitis (∼ 25% of cases)
- Gastrointestinal symptoms: associated with chronic inflammatory bowel disease (∼ 5–10% of cases, see also: colitis ulcerous or Crohn's disease)
- Prostatitis
- Fatigue, weakness, fever, weight loss
- Restrictive pulmonary disease due to decreased mobility of the spine and thorax
- Cardiac: aortic valve insufficiency, atrioventricular blocks
- Kidney: IgA-nephropathy [10].

2 InterCriteria decision making approach

The concepts of InterCriteria analysis is based on the apparatus of index matrices (IMs), [5] and intuitionistic fuzzy sets (IFSs), [1, 2, 3, 4]. The approach is specifically developed for situations in multicriteria decision making, where some of the criteria come at a higher cost than others, for instance are harder, more expensive, more human resource or time consuming to measure or evaluate. While these criteria are considered unfavorable, the method aims to identify high enough levels of correlation between these criteria and others that are easier, cheaper or quicker to measure or evaluate, in order to disregard the unfavorable ones from the further decision making process, [6, 9].

Intuitionistic fuzzy sets (IFSs) are one of the most popular extensions of Zadeh's concept of fuzzy sets. Fuzzy sets extend the classical notion of set by introducing membership function,

allowing the gradual assessment of the membership of elements to a set with values from the [0; 1]-interval. Furthermore, Atanassov's intuitionistic fuzzy sets extend the concept of fuzzy sets by introducing an additional function of non-membership, evaluated in the same interval, with the requirement that both degrees are in the unit interval, and their sum also belongs to that interval. Briefly, the IFS is formally denoted by $A = \{\langle x, \mu_A(x), v_A(x)\rangle \mid x \in E\}$, where $\mu_A(x)$ defines the membership of an element x to the set A, evaluated in the [0; 1]-interval; $v_A(x)$ defines the non-membership of the element x to the set A, where $\mu_A(x) \in [0; 1]$, $v_A(x) \in [0; 1]$, and $(\mu_A(x) + v_A(x)) \in [0; 1]$.

Comparison between elements of two IFSs, involves pairwise comparisons between the degrees of membership and non-membership of the elements of both sets.

Let us have an index matrix (IM) with elements $a_{p,\,q}$, $p = 1, ..., m$, $q = 1, ..., n$,

$$
M = \begin{array}{c|cccccccc}
 & O_1 & \cdots & O_k & \cdots & O_l & \cdots & O_n \\
\hline
C_1 & a_{C_1,O_1} & \cdots & a_{C_1,O_k} & \cdots & a_{C_1,O_l} & \cdots & a_{C_1,O_n} \\
\vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\
C_i & a_{C_i,O_1} & \cdots & a_{C_i,O_k} & \cdots & a_{C_i,O_l} & \cdots & a_{C_i,O_n} \\
\vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\
C_j & a_{C_j,O_1} & \cdots & a_{C_j,O_k} & \cdots & a_{C_j,O_l} & \cdots & a_{C_j,O_n} \\
\vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\
C_m & a_{C_m,O_1} & \cdots & a_{C_m,O_j} & \cdots & a_{C_m,O_l} & \cdots & a_{C_m,O_n}
\end{array} \,,
$$

where C_p is a criterion, taking part in the evaluation; O_q is an object, being evaluated; $a_{p,\,q}$ is the evaluation of the q-th object against the p-th criterion, and it is defined as a real number or another object that is comparable according to relation R with all the rest elements of the index matrix M, so the relation ($R(a_{C_k O_i}, a_{C_k O_j})$ holds for each I, j, k. The relation R has dual relation $\overline{R}$, which is true in the cases when relation R is false, and vice versa.

If the number of cases for which the relations ($R(a_{C_k O_i}, a_{C_k O_j})$ and $R(a_{C_l O_i}, a_{C_l O_j})$ are simultaneously satisfied is $S_{k,l}^{\mu}$ and the number of cases for which the relations $R(a_{C_k O_i}, a_{C_k O_j})$ and its dual $\overline{R}(a_{C_l O_i}, a_{C_l O_j})$ are simultaneously satisfied is $S_{k,l}^{v}$, then

$$0 \le S_{k,l}^{\mu} + S_{k,l}^{v} \le \frac{n(n-1)}{2},$$

since the total number of pairwise comparisons between the object is $n(n-1)/2$. For every k, l, such that $1 \le k \le l \le m$, and for $n \ge 2$ two numbers are defined

$$\mu_{C_k,C_l} = 2\frac{S_{k,l}^{\mu}}{n(n-1)}, v_{C_k,C_l} = 2\frac{S_{k,l}^{v}}{n(n-1)},$$

$$0 \le S_{k,l}^{\mu} + S_{k,l}^{v} \le \frac{n(n-1)}{2}.$$

The pair, constructed from these two numbers, plays the role of the intuitionistic fuzzy evaluation of the relations that can be established between any two criteria C_k and C_l. In this way the index matrix M that relates evaluated objects with evaluating criteria can be transformed to another index matrix M^* that gives the relations among the criteria:

$$M^* = \frac{\begin{array}{ccc} C_1 & \cdots & C_m \end{array}}{\begin{array}{c} C_1 \\ \vdots \\ C_m \end{array} \left| \begin{array}{ccc} \langle \mu_{C_1,C_1}, \nu_{C_1,C_1} \rangle & \cdots & \langle \mu_{C_1,C_m}, \nu_{C_1,C_m} \rangle \\ \vdots & \ddots & \vdots \\ \langle \mu_{C_m,C_1}, \nu_{C_1,C_m} \rangle & \cdots & \langle \mu_{C_m,C_m}, \nu_{C_m,C_m} \rangle \end{array} \right.}.$$

Alternatively, it is practical to work with two index matrices M^μ and M^ν, rather than with the index matrix M^* of IF pairs.

The final step of the algorithm requires defining the values of thresholds for both the membership and the non-membership, against which we evaluate the precision of the ICA decision making. We call that two criteria are in relation of either 'positive consonance', or 'negative consonance', or 'dissonance', depending on their InterCriteria pair's comparison with these two defined threshold values. Let $\alpha, \beta \in [0; 1]$ be the threshold values, against which we compare the values of μ_{C_k, C_l} and ν_{C_k, C_l}. We call these criteria C_k and C_l are in:

- (α, β)-positive consonance, if $\mu_{C_k,C_l} > \alpha$ and $\nu_{C_k,C_l} < \beta$;
- (α, β)-negative consonance, if $\mu_{C_k,C_l} < \beta$ and $\nu_{C_k,C_l} > \alpha$;
- (α, β)-dissonance, otherwise.

3 Behterev's Disease Analysis

A conclusion was reached that if systematically and duly applied, the already developed specific kinesitherapy program will contribute to the improvement of the health status and thus, of the quality of life the patients suffering from Rheumatoid spondylitis [13].

The aim of this research is to study the health status of patients suffering from Rheumatoid spondylitis and its influence on their quality of life. It includes patients aged 25-80. They are divided into two groups – an experimental one – 43 patients (33 female and 10 men) and a check one – 45 patients (38 female and 7 men) [13].

Research method – standard test SF-36

The Short Form (36) Health Survey is a 36-item, patient-reported survey of patient health. The SF-36 is a measure of health status and an abbreviated variant of it, the SF-6D, is commonly used in health economics as a variable in the quality-adjusted life year calculation to determine the cost-effectiveness of a health treatment. The original SF-36 came out from the Medical Outcome Study, MOS, done by the RAND Corporation. Since then a group of researchers from the original study released a commercial version of SF-36 while the original SF-36 is available in public domain license free from RAND. A shorter version is the SF-12, [1]. If having only

adequate physical and mental health summary scores is of interest, "then the SF12 may be the instrument of choice". [13]

The test consist of 36 questions. It has got an 8-scale profile of the functional results of health and general condition. The 36 points of the questionnaire are grouped into 8 scale:

1. Physical functioning (PF) – measuring the degree to which any physical effort is limited by the physical condition. The low levels on this scale show that the physical activity of the patient is considerably limited by his health condition.

2. Role functioning based by physical conditional (RP) – the impact of the physical condition on the daily role activity. The low levels on this scale show that the daily routine of the patients is considerably limited by their physical condition.

3. Bodily pain (BP) – and its impact on the ability to perform every day activities, including indoor and outdoor work. The low levels on this scale show that the level of pain considerably limits the activity of the patient.

4. General health (GH) – patients' evaluation of their own health status at any specific moment and their prospects for treatment. The lower the rating on this scale, the lower the evaluation of the health status.

5. Vitality (VT) – it means the feeling of invigoration and energy, or, on the other hand, the feeling of weakness. The low rating indicates lassitude of the patient and decrease of his ability.

6. Social functioning (SF) – defines the degree of limitation of the social activity by the physical and emotional conditional. The low rating show considerable limitation of the social contacts, decreased communication based on poor physical and emotional conditional.

7. Role functioning based by emotional conditional (RE) – means evaluation of the degree to which the emotional conditional prevents the patient from the normal execution of his professional duties or other daily routine. The low rating on the scale are interpreted as a limitation in doing the everyday work based on poor emotional condition.

8. Mental health (MH) – it is characterized by the appearance of a depressive mood, anxiety and decrease in the percent of positive emotions. The low levels on the scale show presence of depressive, anxious emotions, mental failure. [16].

The main concept of the ICA approach is to estimate the objects on the basis of several criteria. In the current study, we apply the ICA analysis over the results of a medicine and physiotherapeutic treatment and kinesitherapeutical program applied, based on the above mentioned indicators.

Methodology of kinesitherapy

Specific tasks of the kinesitherapy:

1. General improvement of the organism and improving the psycho- emotional tonus;

2. Increase of resistant forces and prevention of recidivism;

3. Muscle strengthening around the joints, as well as of the weak hypotrophic muscles and muscular groups, leading of strengthening of grippings, improvement of coordination of the fine movements of the fingers (precise grippings), taking part in everyday life and labour activities.

4. Improvement of the muscle nutrition;

5. Improvement of the volume of movement of the joints;
6. Pain decrease;
7. Overcoming of muscular disbalance and prevention of deformation. [13].

Means of kinesitherapy:
1. Passive exercises for the wrist and the hand – the movements are performed carefully and under control, doing passive exercises following the physiological axes of the three movement planes. The exercises include flexion, extension, abduction, adduction and circumduction of the wrist joint. The interphalangeal joints and the metacarpophalangeal ones are done in the sagital plane. Metacarpophalangeal joints of the fingers and the carpometacarpal joint of the thumb are done in the frontal plane performing circumduction at the same time.
   The exercises of the finger joints are done separately or combined with those of the wrist. Most literary sources mention positive effect on the syndrome of pain as well as improving the functional volume of movement.
2. Analytical exercises – they come after the passive exercises, following the principles of gradualness and diversity. The active analytical exercises included in the programme are performed in a state of eliminated gravitation and their performance is held in a volume of movement reaching pain. The pace is slow, including slow repetition.
3. Terrain treatment – includes trading of different types of walking, due to the tendency to flat food in patients with Rheumatoid spondylitis. The performance of these activities is held in special zones with suitable up and down paths and rest places. The pace is slow to moderate. 60-80 paces per minute are performed, counted by a pedometer.
4. Underwater gymnastics – a partial bath tub is used to perform exercises in water for upper limbs. Water possesses the following features – thermal and mechanical stimulation. Underwater gymnastics has got many advantages. It helps reach certain physical influences on the body, which are not possible in air environment. The effect is due to the physical qualities of the water: temperature, lifting force, water resistance. These exercises are 10 times easier to do which enables their correct and painless performance. The join edema is also considerably influenced. The tissues surrounding the joints become softer and more elastic, it has got a pain release effect, too.
5. Exercises aiming at developing a muscular corset – these are exercises which lead to relaxation of the static muscles and strengthening of the dynamic muscles using movements against resistance. Their performance result in full balance between static and dynamic muscles and influence the muscular disbalance.
6. Resistive exercises – these are exercises including complex movements of the fingers against a resistance of an elastic band, a silicon pellet and silicon plasticine. The movements should not be with high intensity, the pace is slower and there are fixed rests.
7. Active exercises with and on apparatuses – There are exercises for the fine movements of the upper limbs including suitable tools, e.g. wooden puzzles with different gripping size, rings, rubber or silicon pellets.
8. Manual mobilization of peripheral joints – the joint mobilization techniques used lead to decrease of stiffness and support of the available mobility of the joints.

- Interphalangeal joints – the mobilization is performed in latero-lateral, dorzo-ventral direction, the traction being applied in both directions. The fixing is on the proximal phalangue and mobilization is carried moving the distal phalangue. To keep the latero-lateral direction the thumbs and the index finders are placed side-line, and for the dorsal direction – above and under the phalangues.
- The mobilization of the metacarpophalalangeal joints and the heads of the metacarpal bones is performed in latero-lateral, dorso-ventral direction after traction, rotation also being included. The fixing and the mobilization are done with the thumb and index finger of the fixing and mobilizing hand, positioned crosswise to the direction of sliding.
- Carpal joints – if palmar flexion is limited we perform mobilization of the proximal line of carpal joints towards the radius and the ulnae. We perform the manipulation fixing the two thumbs against the thorn growths of radius and ulnae and the index fingers are put palmar on the upper line. After traction we do mobilization of the upper line in dorsal direction. If dorsal flexion is limited we mobilize the dorsal line of carpal bones towards the proximal line in palmar direction. With the opposite hand we hold the upper line of the carpal bones, dorsally, under the radius and ulnae bone. The other hand holds dorsally the lower line. After the traction the mobilization is performed dorso-palmar.

9. Isometrical exercises – they should be done carefully and suitable amount, for a relieved starting position for in the corresponding joints. These exercises are suitable in a slow pace and without pain even in the acute stage. Isometrical muscular contractions are also applied with healthy joints in order to sustain the muscular strength and tonus.

10. PNF – The succeous induction phenomenon is used aiming at making the active movements stronger through relaxation of muscles taking part in other activities. This influences the gradual and correct embedding affected joint into the limb movement model.

11. Mechanotherapy – we use tools to facilitate the movements in the wrist joint, the fingers, the gripping, movements in the radio-ulnar joint - – supination and pronation, abduction, adduction as well as inner and outer rotation of the shoulder joint. Tools are combined movement in more than one joint in the upper limbs are also used. At the beginning the exercises are done with the assistance of the kinesitherapist until the pain syndrome is released and the functional mobility of the joints is influenced.

12. Treatment with a position – it is implied both in the acute, post-acute and chronic state. It the first two states the treatment with a position aims mainly at influencing the pain and by putting the affected joint in a physiological position at preventing the atrophy of the weak (dynamic) muscles as well as the muscular disbalance. In the chronical state the treatment with position is applied in the final stage of the complex and its aim is to improve and recover the affected joints through muscular relaxation round it. [13].

The loading is gradually increased. The duration of the kinesitherapy procedure is 45-50 min, the pace of the exercises is moderate, making less and shorter pauses. In order to strengthen certain muscles and muscular groups we use resistance overcome.

Table 1. Exemplary methodology of kinesitherapy

	Contents	Dosage	Tasks	Instructions
Preparatory part	General exercises for all parts of the body, active and against manual resistance alternated with respiratory exercises and exercises for relaxation.	10 min.	A total tonic effect on all organs and systems. Improving trophic processes, strengthening muscles and paintain the normal volume of movement in the intact joints, relaxation.	Performance from a relieved starting position for affected joints in full volume combined with breathing. Slow pace.
Main part	1. Special exercises for all joints on the upper and lower limbs, the spine, active, against manual resistance, isotonical exercises. 2.Exercises with tools, ball, rolling pin, specially designed tools for the distal sections of the limbs, mobilization, and passive movement of a affected joints, massage. 3.Walking exercises, respiratory exercises, relaxing exercises. 4. Exercises are performed from relieved starting position for the affected joints in full volume combined with breathing.	30 min.	1. Improving blood circulation and trophic effects on the affected joints and surrounding tissues, strengthening of the surrounding muscular, increasing the volume of movement. 2. Improving muscle tone and increasing volume of movement. Improving the function of affected joints. Overcome of contractures. 3.Improving the metabolic processes in the body, restoring the locomotive function.	1. Performance from a relief starting position for affected joints, slow pace and maximum amplitude. 2.Movements are combined with breathing, slow pace, mobilization is performed within the limit of articular movement, passive moves without force, gait correction. 3. Performance from a relieved starting position for affected joints in full volume combined with breathing. Slow pace.
Closing part	Respiratory exercises , exercises for relaxation, treatment through position	10 min.	Emotional impact and patient comfort.	Instructions are given after the kinesitherapy procedure to place the limbs in one hour relaxing position.

The results of the study (beginning and end) are presented in the article [17]. These have been analysed applying InterCriteria decision making approach. The results are presented in Tables 2 and 3, where the criteria are labeled as follows: PF – Physical functioning, RP – Role

functioning based on physical condition, BP – bodily pain, GH – General health condition, MH – mental health, RE – Role functioning based on emotional condition, SF – social functioning, VT – vitality.

μ	PF	RP	BP	GH	MH	RE	SF	VT
PF	1	0.5	0.833333	0.666667	0.5	0.333333	0.666667	0.666667
RP	0.5	1	0.333333	0.5	0.666667	0.5	0.5	0.5
BP	0.833333	0.333333	1	0.833333	0.333333	0.166667	0.833333	0.5
GH	0.666667	0.5	0.833333	1	0.166667	0	1	0.333333
MH	0.5	0.666667	0.333333	0.166667	1	0.833333	0.166667	0.833333
RE	0.333333	0.5	0.166667	0	0.833333	1	0	0.666667
SF	0.6667	0.5	0.833333	1	0.166667	0	1	0.333333
VT	0.666667	0.5	0.5	0.333333	0.833333	0.666667	0.333333	1

Table 2. Membership pairs of the intuitionistic fuzzy InterCriteria correlations

ν	PF	RP	BP	GH	MH	RE	SF	VT
PF	0	0.5	0.166667	0.333333	0.5	0.666667	0.333333	0.333333
RP	0.5	0	0.666667	0.5	0.333333	0.5	0.5	0.5
BP	0.166667	0.666667	0	0.166667	0.666667	0.833333	0.166667	0.5
GH	0.333333	0.5	0.166667	0	0.833333	1	0	0.666667
MH	0.5	0.333333	0.666667	0.833333	0	0.166667	0.833333	0.166667
RE	0.666667	0.5	0.833333	1	0.166667	0	1	0.333333
SF	0.333333	0.5	0.166667	0	0.833333	1	0	0.666667
VT	0.333333	0.5	0.5	0.666667	0.166667	0.333333	0.666667	0

Table 3. Non-membership pairs of the intuitionistic fuzzy InterCriteria correlations

4 Results analysis

There is strong correlation between the following two indicators – social functioning and health condition, as seen from the obtained results.

The correlation mentioned is typical because one's health condition determines their social functioning, to a large extend. When a person is in a positive health and emotional condition they feel confident and their social functioning is improved. And vice versa, if a person is sick this leads to negative feelings (both emotionally and physically) and prevents them from having a normal social life.

Relatively high correlation is also seen between the following criteria:
- Bodily pain and physical development – When the patient does not suffer pain, he is capable of developing physically. All activities which do not cause pain are performed by the patient with willingness and contentment. On the other hand, if the pain is persistent if it is constant and intensive, the patient gives up performing his activities. This leads to worsening of his physical development.

- The same applies to the health condition and pain intensity. When health condition is satisfactory, the pain intensity decreases and vice versa.
- Social functioning and bodily pain.
- Vitality and mental health – When our mental health is satisfactory, our vitality increases.

There are some of the criteria that show quite weak correlation, e.g.:

- Health condition and role functioning based on emotion conditions – in this case the correlation between the two criteria is quite low due to their difference and their being independent from each other. Patients should be able to observe fairly their disease and momentary state.
- Social functioning and role functioning based by emotional conditional.

5   Conclusions

The article describes a new method of analyzing the treatment results of patients with Behterev's disease in order to improve the process of taking decisions about the treatment course – InterCriteria Decision Making Approach.

The results achieved by the InterCriteria decision making approach in the presented paper once again confirm that the health condition depends on the emotional condition and determines the social functioning of the patients under observation. The present paper proves the application of the original InterCriteria decision making approach, which eases the analysis if the relations between the criteria, giving better clinical quality.

The results obtained from the under taken research develop further the applicability of the original, defining new approach to decision-making process – InterCriteria Analyses.

Acknowledgements

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