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Generalized Net Model of Non-Traumatic Elbow Pain Diagnosing

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Abstract: Elbow pain is a commonly occurring symptom in primary care. The diagnosis of this symptom requires elimination of many conditions with similar presentation and a logical step-by-step approach to the history as well as a series of functional investigations. Non-traumatic elbow pain can be caused by different pathologies in any component of the joint including tendons, bursae, bones, nerves and muscles. For that reason, in the present study we propose a mathematical model based on the generalized net theory, which highlights the diagnostic steps for patients with non-traumatic elbow pain.
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1 Introduction

The elbow articulation is made up of four joints and three highly congruous joint surfaces and is considered as a trochoginglymoid joint [7] with two degrees of freedom (flexion/extension and pronation/supination). This unique osseous complex provides the elbow excellent static stabilization, which is enhanced by the ulnar collateral ligament, the lateral collateral ligament, and the elbow joint capsule. On the other hand, the functional anatomy of the elbow along with a wide range of dynamic exertion forces predisposes its components to wide range of injuries, particularly with repetitive motions and overuse. Problems that develop in a patient's elbow often manifests with pain and tenderness. Causes of non-traumatic pain may include overuse, inflammation or ongoing degenerative processes. Some of the most common causes of non-traumatic elbow pain are epicondylitis (lateral or medial), arthritis, peripheral nerve entrapment syndromes, muscle tendinopathies and olecranon bursitis. Lateral epicondylits, olecranon bursitis and medial epicondylitis represent more than 90% of the diagnoses [2]. In some cases, however the elbow pain can be referred from other distant structures of the body, mostly from the cervical spine and the shoulder.

Diagnosing the underlying etiology of elbow pain can be difficult, and early defining of the form of the disease is essential for the choice of appropriate treatment. The location and quality of elbow pain can generally localize the injury to one of the four anatomic regions: anterior, medial, lateral, or posterior [6]. Most patients with anterior elbow pain have an element of tendinosis, usually at the insertion of the biceps tendon on the radial tuberosity or arthritis. Lateral elbow pain is well localized with tenderness over the supracondylar ridge. Physical examination reveals maximal tenderness approximately 1.5 cm distal to the epicondyle at the origin of the extensor carpi radialis brevis. This finding often suggests lateral epicondylitis ("tennis elbow") as a primary diagnosis. Medial elbow pain arises from the medial epicondyle and is well localized it is aggravated by repetitive use of the forearm and wrist. The point of maximal tenderness is usually at the insertion of the flexor-pronator mass, 5 to 10 mm distal and anterior to the medial epicondyle [5]. The lateral elbow is affected four to 10 times more often than the medial side [4]. Olecranon bursitis is the most common superficial bursitis and is a common cause of posterior elbow pain and swelling [1]. Initial evaluation of the patient with elbow pain should begin with detailed history and systematic approach towards assessment of nature, onset, and duration of pain and associated symptoms. Then as a part of the investigation it is essential to perform specific functional tests and evaluation of the passive and active range of motion. In general, the diagnostic criteria used for identification of the non-traumatic elbow pain should perform two important functions. First they should confirm the elbow as a primary source of symptoms and second the criteria must identify specific anatomical areas of elbow involvement. From that point of view, a certain strategy is necessary to guide clinical decisions for patients with elbow pain. The objective of this study is to present a Generalized Net model (GN-model) of non-traumatic elbow pain diagnosing. The proposed model highlights the diagnostic algorithm and it represents an application of Generalized Nets in orthopedics and traumatology.

2 Generalized Net Model of Non-Traumatic Elbow Pain Diagnosing

Generalized nets (GNs; see [3]) are an apparatus for modeling of parallel and concurrent processes, developed as an extension of the concept of Petri nets and some of their modifications. The presented GN-model has parallel futures with previous models for medical diagnosing [8, 9, 10], but is the first one which represents the diagnosing plan non-traumatic elbow pain. In general, the GNs may or may not have some of the components in their definition. GNs which do not have some of the components form special classes called reduced GNs ([4]). Here is represented a reduced GN-model of non-traumatic elbow pain diagnosing. The proposed model (Fig. 1) has 23 places and the following set of transitions:

$$A = \{Z_1, Z_2, Z_3, Z_4, Z_5, Z_6, Z_7\}$$

These transitions describe the following processes:

- Z_1 represents the personal record (data) of the patient,
- Z_2 – the results from the initial examination,
- Z_3 – the results from the x-ray and the laboratory tests,
- Z_4 – the results from the functional tests and pain localization,
- Z_5 and Z_6 – the results from the special functional tests,
- Z_7 – the possible diagnosis and the cause of pain in the elbow joint.

The GN-model contains 6 types of tokens: α, β, μ, η, γ and δ. At the time of duration of the GN-functioning, some of these tokens can split, generating new tokens, that will transfer in the net obtaining respective characteristics, and also in some moments they will unite with some of tokens α, β, μ, η, γ and δ. Some of the model transitions contain the so called "special place" where a token stays permanently and collects information about the specific parts of the diagnosing process which it represents as follows:

- In place l_3, token β stays permanently and collects the overall information obtained from the diagnostics steps in the medical record of the patient.
- In place l_7, token μ stays permanently and collects information about the medical history of the patient, results from the physical examination and the results from the laboratory testing.
- In place l_{11}, token η stays permanently and collects information about the results from the X-ray and the laboratory tests.

- In place l_{15}, token γ stays permanently and collects the information obtained from the functional tests and localization of pain.
- In place l_{23}, token δ stays permanently and collects the overall information from the imaging and laboratory tests, special provocative tests.

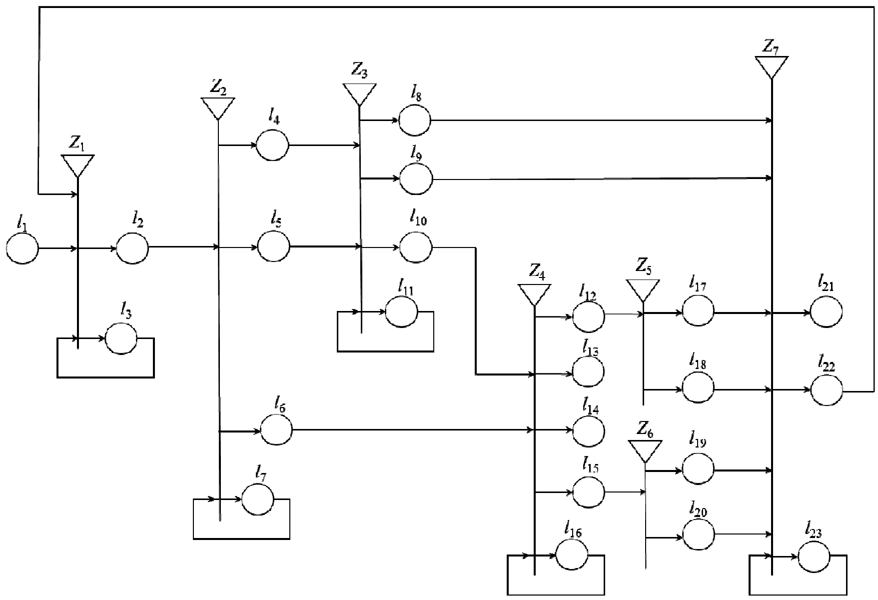

Figure 1. Generalized net model of non-traumatic elbow pain diagnosing.

During the GN-model functioning, the α-tokens will unite with the tokens from the rest types (β, μ, η, γ and δ). After that, some of these tokens can split in order to generate new α-tokens obtaining corresponding characteristics. When e.g. there are some α-tokens or β-tokens (α_1, α_2, α_3, β_1 and eventually β_2), on the next time-moment, all they will unite with a token from another type.

Token α enters the net with initial characteristic "*patient with elbow pain*" in place l_1. The transitions of the GN-model have the following forms:

$$Z_1 = \langle \{l_1, l_3, l_{22},\}, \{l_2, l_3,\}, r_1 \rangle,$$

where:

$$r_1 = \begin{array}{c|cc} & l_2 & l_3 \\ \hline l_1 & false & true \\ l_3 & true & true \\ l_{22} & false & true \end{array}$$

The tokens from the three input places of transition Z_1 enter place l_3 and unite with token β with the above mentioned characteristic. On the next time-moment, token β splits to two tokens – the same token β and token α_1. Token α_1 enters place l_2 and there it obtains a characteristic:

"*perform a detailed medical history and the initial physical examination*".

The transition Z_2 has the following form:

$$Z_2 = \langle \{l_2, l_7\}, \{l_4, l_5, l_6, l_7\}, r_2 \rangle,$$

where:

$$r_2 = \begin{array}{c|cccc} & l_4 & l_5 & l_6 & l_7 \\ \hline l_2 & false & false & false & true \\ l_7 & W_{7,4} & W_{7,5} & W_{7,6} & true \end{array}$$

and,

- $W_{7,4}$ = "*patient with previous history of traumatic events in the elbow joint* ∧ *chronic pain, stiffness, reduced range of motion and cracking sounds from the elbow joint*",
- $W_{7,5}$ = "*patient with symptoms of inflammation and swelling*",
- $W_{7,6}$ = "*patient with no previous history of traumatic events in the elbow joint* ∨ *progressive pain, tenderness and reduced grip strength*".

The tokens from the three input places of transition Z_2 enter place l_7 and unite with token μ with the above mentioned characteristic. On the next time-moment, token μ splits to four tokens – the same token μ and tokens α_1, α_2 and α_3.

When the predicate $W_{7,4}$ is true, token α_1 enters place l_4 and there it obtains a characteristic:

"*consider degenerative joint disease as a possible diagnosis: perform an x-ray*".

When the predicate $W_{7,5}$ is true, token α_2 enters place l_5 and there it obtains a characteristic:

"*consider inflammatory joint disease as a possible diagnosis: perform an x-ray and laboratory tests*".

When the predicate $W_{7,6}$ is true, token α_3 enters place l_6 and there it obtains a characteristic:

"*consider inflammatory disease of the soft tissues around the elbow or repetitive stress condition as a possible diagnosis: perform special functional tests and evaluate the exact location of the pain*".

The transition Z_3 has the following form:

$$Z_3 = \langle\{l_4, l_5, l_{11}\}, \{l_8, l_9, l_{10}, l_{11}\}, r_3\rangle,$$

where:

$$r_3 = \begin{array}{c|cccc} & l_8 & l_9 & l_{10} & l_{11} \\ \hline l_4 & false & false & false & true \\ l_5 & false & false & false & true \\ l_{11} & W_{11,8} & W_{11,9} & W_{11,10} & true \end{array}$$

and,

- $W_{11,8}$ = "*the X-ray image shows: there are osteophytes, joint narrowing and subchondral sclerosis of the elbow joint* $\wedge$ *normal CRP and normal ESR laboratory results*",
- $W_{11,9}$ = "*the x-ray image shows: there are joint erosions* $\wedge$ *High-positive RF and Abnormal CRP laboratory results*",
- $W_{11,10} = \neg W_{11,8} \wedge \neg W_{11,9}$.

The tokens from the three input places of transition Z_3 enter place l_{11} and unite with token η with the above mentioned characteristic. On the next time-moment, token η splits to two tokens – the same token η and token α_1.

When the predicate $W_{11,8}$ is true, token α_1 enters place l_8 and there it obtains a characteristic:

"*consider osteoarthritis as a possible cause of elbow pain*".

When the predicate $W_{11,9}$ is true, token α_1 enters place l_9 and there it obtains a characteristic:

"*consider rheumatoid arthritis as a possible cause of elbow pain*".

When the predicate $W_{11,10}$ is true, token α_1 enters place l_{10} and there it obtains a characteristic:

"*exclude common types of elbow arthritis,*
consider further functional testing".

The transition Z_4 has the following form:

$$Z_4 = \langle \{l_6, l_{10}, l_{16}\}, \{l_{12}, l_{13}, l_{14}, l_{15}, l_{16}\}, r_4 \rangle,$$

where:

$$r_4 = \begin{array}{c|ccccc} & l_{12} & l_{13} & l_{14} & l_{15} & l_{16} \\ \hline l_6 & false & false & false & false & true \\ l_{10} & false & false & false & false & true \\ l_{16} & W_{16,12} & W_{16,13} & W_{16,14} & W_{16,15} & true \end{array}$$

and,

- $W_{15,12}$ = "*there is pain at the insertion of the flexor-pronator mass, 5 to 10 mm distal and anterior to the medial epicondyle accompanied by pain during resisted pronation*",
- $W_{15,13}$ = "*there is anterior elbow pain during resisted flexion and resisted supination of the forearm*",
- $W_{15,14}$ = "*there is posterior elbow pain during resisted or full extension* $\vee$ *posterior elbow pain and posterior elbow swelling*",
- $W_{15,15}$ = "*there is pain and maximal tenderness approximately 1 cm distal to the epicondyle at the origin of the extensor carpi radialis brevis*".

The tokens from the three input places of transition Z_4 enter place l_{15} and unite with token γ with the above mentioned characteristic. On the next time-moment, token γ splits to two tokens – the same token γ and token α_1.

When the predicate $W_{16,12}$ is true, token α_1 enters place l_{12} and there it obtains a characteristic:

"*consider medial epicondylitis as a possible diagnosis,*
perform special provocative tests ".

When the predicate $W_{16,13}$ is true, token α_1 enters place l_{13} and there it obtains a characteristic:

"*consider biceps tendinopathy as a possible diagnosis,*
send patient to further imaging tests".

When the predicate $W_{16,14}$ is true, token α_1 enters place l_{14} and there it obtains a characteristic:

"*consider triceps tendinopathy, posterior impingemet or olecranon bursitis*
as a possible diagnosis, send patient to further imaging tests".

When the predicate $W_{16,15}$ is true, token α_1 enters place l_{15} and there it obtains a characteristic:

"*consider lateral epicondylitis as a possible diagnosis,*
perform special provocative tests".

The transition Z_5 has the following form:

$$Z_5 = \langle \{l_{12}\}, \{l_{17}, l_{18}\}, r_5 \rangle,$$

where:

$$r_5 = \begin{array}{c|cc} & l_{17} & l_{18} \\ \hline l_{12} & W_{12,17} & W_{12,18} \end{array}$$

and,

- $W_{12,17}$ = *"pain during resisted wrist flexion and pronation, negative Tinel's sign, negative carpal tunnel syndrome test"*,
- $W_{12,18} = \neg W_{12,17}$.

When the predicate $W_{12,17}$ is true, token α_1 enters place l_{17} and there it obtains a characteristic:

"*medial epicondylitis is the cause of the elbow pain*".

When the predicate $W_{12,18}$ is true, token α_1 enters place l_{18} and there it obtains a characteristic:

"*possible diagnosis of the patient is carpal tunnel syndrome"*.

The transition Z_6 has the following form:

$$Z_6 = \langle \{l_{15}\}, \{l_{19}, l_{20}\}, r_5 \rangle,$$

where:

$$r_6 = \begin{array}{c|cc} & l_{19} & l_{20} \\ \hline l_{15} & W_{15,19} & W_{15,20} \end{array}$$

and,

- $W_{15,19}$ = *"positive Cozen's test, positive Thomson's manoeuvre, negative Tinel's sign"*,
- $W_{15,20} = \neg W_{15,19}$.

When the predicate $W_{15,19}$ is true, token α_1 enters place l_{19} and there it obtains a characteristic:

"*lateral epicondylitis is the cause of the elbow pain*".

When the predicate $W_{15,20}$ is true, token α_1 enters place l_{20} and there it obtains a characteristic:

"*possible diagnoses of the patient are cubital tunnel syndrome or plica syndrome*".

The transition Z_7 has the following form:

$$Z_7 = \langle \{l_8, l_9, l_{17}, l_{18}, l_{19}, l_{20}, l_{23}\}, \{l_{21}, l_{22}, l_{23}\}, r_7 \rangle,$$

where:

$$r_7 = \begin{array}{c|ccc} & l_{21} & l_{22} & l_{23} \\ \hline l_8 & false & false & true \\ l_9 & false & false & true \\ l_{17} & false & false & true \\ l_{18} & false & false & true \\ l_{19} & false & false & true \\ l_{20} & false & false & true \\ l_{23} & true & true & true \end{array}$$

The tokens from the all input places of transition Z_7 enter place l_{23} and unite with token δ with the above mentioned characteristic. On the next time-moment, token δ splits to three tokens – the same token δ and tokens β and β_1. The two new tokens enter respectively in place l_{21} and place l_{22}, with the same characteristic as the characteristic obtained from the previous time step. Token β from place l_{22} returns to place l_3 to extend the personal record of the current patient.

3 Conclusion

The so described GN-model may provide a framework that can be used by primary care practitioners to guide diagnostic approach to patient with non-traumatic elbow pain, enabling more accurate and efficient identification of potential causes and would assist in optimizing patient outcomes and more effective treatment and rehabilitation. The method proposed here, will accurately identify the various steps during the diagnosing processes and significantly improve the health care level.

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