MEASUREMENT OF PARAMETERS OF A SKIN WITH A SCAR IN VIVO AND THE INFLUENCE OF PHYSIOTHERAPY

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Abstract: A scar remaining after a radical mastectomy plays an important role in an occurrence of post-surgery disorders of a motion system. A disorder can manifest as a myofascial pain most frequently in a humeral plexus on the operated side and in the corresponding muscle chains that cross the scar.

This experiment focuses on a mapping of a relatively long-term behavior of a scar. The goal is to describe the changes of a visco-elasticity of a tissue in the scar area as a consequence of physical therapy employing two different methods. The first method measures a deformation of a tissue during an impression of a probing stylus. The second method tests a protractability of a tissue in the scar area through a matrix identification of a skin deformation. Both employed methods serve for a scanning of the tissue condition for comparison purposes (e.g. before and after a therapy)

The measurement is performed on patients that have no serious post-surgery complications with a sense of an attending physician.

Introduction

An operation wound always causes a change of character of a skin. It namely interferes its mechanical function, logistic, perception. A skin is a complex organ. Its complexity comes mainly from its composite structure and from a wide range of influence that it has to other systems e.g. breathing system, neuro-muscular system, psychic system and hormomal and immune systems.

A skin is usually a subject of medical as well as technical studies. Most clinical studies are from a plastic surgery field for which cosmetic properties of a skin are the most important. These studies usually employ some reologic models that describe Borges and Langer lines omitting a composite structure of a skin [7]. Several studies employ an extensometer to measure skin properties[8, 13, 15, 16].

A common weaknesses of all in-vivo measurement methods are an interpretation obtained values and repeatability of measurements due to individuality of patients (age, thermoregulation, genetic dispositions, etc.) It is clearly described in a study of J.A.CLARK [8] that focuses on a measurement of hyperthrophic scars on an antebrachium using the Evance extensometer [8, 16].

Physical characteristics of a skin are very individual for every person and influences of individual properties and aspects usually combine and interfere. Identification of exact mechanical characteristic of a skin in vivo is therefore a complex problem.

The goal of some other clinical studies is often to prove an influence of some treatment method (e. g. physiotherapy LEWIT, OLŠANSKA [20]) usually without employing any reologic model.

A breast cancer is the most frequent women carcinoma – 30 % of all women carcinomas (1). In later stages according to the TNM classification) radical mastectomy followed by chemotherapy or radiotherapy is a survival solution for patients.

After radical mastectomy a motor system is disturbed and overloaded in consequence of surgical and radiological interventions [11,12]and often becomes a source of pain which consequently decreases the quality of life[2, 18, 19]. The goal of this study is to observe these coming-up processes in vivo and to forecast their manifestation based mainly on an observation of a post-surgery scar. In this investigation are employed clinical methods (kinesiology analysis, barrier phenomenon after LEWIT [3] as well as physical and biomechanical methods.

Physical identification methods are focused to identification of visco-elasticity of skin. Examination is based on a comparison analysis of images of the observed tissue conditions captured by the used methods always before and after a treatment.

This study focuses on patients after a modified radical mastectomy after Madden, which is a very frequent intervention in a relation with a breast cancer (according to TNM classification). The operative technique is the ablation of mamma with a dissection of axilar nodes[2]. The result is a big scar on chest.

The surrounding of the operation wound is during the operation irreversibly disturbed, especially the neural tissue and blood vessels that are crucial for an optimal behavior of a motor system [2]. A deficiency of a neural and blood support often leads to changes of a strategy of motion of the whole affected region [2, 6].

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Skin generally

Skin participates on many processes in a human body. It has beside others a thermoregulative, protective, metabolic and a sensitive function [2, 5, 17]. Through receptors in a skin are perceived stimulates that are then processed in a CNS. That is why also a skin participates on high-level neuro-muscular processes through which it influences a postural sway and a phasic function of a motor system [6].

Besides others skin is also a tissue full of capilars (lymph and blood), which has big importance in a relation of an occurrence and treatment of a post-surgery lymphoedema [14].

A correct function and structure of skin is very important for optimal behavior of control processes in a human organism which it at many levels influences.

Biomechanics of skin

There are some studies trying to build some mechanical model of a skin with scar but these models are usually very limited and focused to one particular property of skin. For example the study after CERDA[7] describes an experiment with a thin membrane trying to simulate a relationship between a deformation and wrinkling of a skin around a scar and a background tension of a skin. The study showed a dependency between a wrinkling of skin and its orientation with respect to so called Langer and Borges lines. The mechanical model in this study is limited to only a static description of a thin membrane not taking into account a thick composite structure of skin and its dynamics.

From the local biomechanical point of view is skin a complex mechanical system. Its complexity is caused first by the fact, that the skin tissue is highly visco-elastic [5, 9,17], thus it has a highly non-linear behavior encompassing mutual transformations of several types of energy. Nonlinear characteristics are even further complicated by a composite structure of a skin tissue. It is composed namely from several layers with mutually very different characteristics creating one mechanical system [17]. The composite system is moreover strongly locally and globally (Langer lines) anisotrophic The identification methods in our study are restricted to such conditions that it is possible to describe the behavior of a skin by a four-element reologic model with linear elements represented by a net of Zener elements [4].

From the global biomechanical point of view is skin a wrapping of a relatively complex surface of a body that is moreover significantly changing during various movements of the body. The skin must adapt to all these changes. It is possible mainly through two effects, through the ability of the skin to stretch (own elasticity) and through shifting of upper skin layers against deeper ones.

The own elasticity enables the skin to change its size temporarily and through that mainly locally adapt to a change of the surface of the body (e.g. when a muscle contracts or relaxes). A local stretching of the skin causes rising of a skin tension in the respective area and it is more less uniformly transferred and spread to surrounding skin areas. In the case when there are only a slow motions of a large extent as in this measuring method, viscosity plays only a minor role in contrast to elasticity therefore we neglect it.

Normally, upper skin layers are separated from subcutis by a layer of ligaments and fascias that has from the biomechanical point of view much higher elasticity and lower viscosity then upper skin layers and subcutis[17]. As a consequence, upper skin layers can shift against subcutis to a relatively large extent. This effect allows a large deformation necessary to adapt to for instance an arm movement to spread to much more outlying regions of skin and due to that, supposing a given elasticity, to minimize the force needed to produce the deformation.

A normal function of skin is often disturbed for instance by a concretion of a skin and subcutis in a scar. In such a case the concretion line makes sort of a barrier that obstructs spreading of a skin deformation. For instance when an arm is elevated a strong deformation (stretch) appear in the whole area from the respective shoulder to lower abdomen along respective muscle chains of the motor system[3,6]. Thanks to the spreading of the deformation to such a large area is the force necessary to produce such a large deformation relatively small. The sources of deformation force are muscles, in the mentioned example mainly the m. latissimus dorsi and other fixators of scapula as well as deep spin muscles. All muscles are normally mutually balanced and adapted to overcome some level of force necessary to deform a skin with every movement [17].

In case of a radical mastectomy, there remains a scar cross-ways the chest and a concretion line related to the scar. When the respective arm is elevated, the concretion line obstructs spreading of the deformation beyond this line. The deformation of the skin in the remaining area (in front of the concretion line) therefore has to be much larger inducing much higher force that is required to produce such deformation. This usually causes overloading of involved chains and consequently their pain. When left untreated for a long time, such situation can lead even to rebuilding of the optimal motion strategy and possibly to some unwanted structural change of the body. Through receptors in a skin are perceived stimules that are then processed in a CNS. When a disturbed skin transmits inoptimally afferent signals to the CNS[6] (e.g. in case of a non-elastic, hypertrophic scar), the efferent feedback into the organism is also modified[6]. The exact ratio of the correct and incorrect afferent/efferent behavior is usually different in every single case. Anyway, it may disturb the mechanics of respiration, e.g. through a decreased range of a respirative motion, or induce a change of motor strategy for humeral girdle.

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Identification of mechanical characteristic of the skin and methods

There are several methods for measurement of a skin deformation that study mechanical properties of a skin both in vitro and in vivo. Some of these methods use a uniaxial or a biaxial extensometer. One of the first extensometers was developed by EVANS AND SIENNOP in 1967 at the University of Glasgow. This extensometer is composed from two arms that are pushed apart by a screw. Arm ends are attached to a skin by a double-sided sticking tape and only one speed of arms is available. This instrument allows observing the whole stressed area [16].

The method developed by WAN ABAS on a Malay University in 1982 focuses on shifts in a stressed area. A matrix of test marks is printed to the observed area and the shifts are derived from a sequence of snapshots of the matrix taken in a course of a deformation [15].

Another type of extensometer was developed in 2002 in mechanical laboratories in Besancon, France. It was a uniaxial extensometer and it was designed only form measurement on antebrachium [13].

Measurement methods based on extensometers are usually quite expensive. I was one of reasons why we tried to use some alternative measurement methods in our experiment.

The goal of this project is to develop and prove physical measuring methods capable of objectively scanning and distinguishing different conditions of the tissue in-vivo, in this experiment namely conditions of a skin tissue after the radical mastectomy before and after therapy.

In case of sufficiently large probing set it may be possible to detect some typical pathological processes still before the pathology manifests as a disorder of a motor system (e.g. pain, reduced range of motion, etc.).

We have chosen the following two of possible measuring methods that have sufficient ability of differentiation of different conditions of the explored tissue, even with relatively low precision of the input data.

Both these methods serve for monitoring of the influence of physical therapy to disturbed skin. In this experiment participate only patients that are under regular medical care and supervision.

Identification of a dynamic deformation response

This method identifies local mechanical properties of the explored skin tissue. It is based on a method originally developed by prof. ĎOUBAL [8] for a measurement of skin properties on other parts of a body so it is currently being modified for a measurement on a chest.

Initially, the tested tissue is locally deformed by depressing a probing stylus into it using a constant force. In our case has the probing stylus a narrow cylindrical shape of 3 mm in diameter with a spherical ending. The value of the initial depressing force is 0.3N. With this stylus size and with this depressing force only a small range deformation influencing mostly the upper skin layers is achieved which can be sufficiently accurately described by a linear biomechanical model. Such a small deformation is painless. It would be possible to explore some deeper skin layers with a larger depressing force, but the respective reologic model would have to be much more complex in order to be sufficiently accurate [8].

In a stable condition, after all transition effects of the initial deformations have finished, the depressing force is then rapidly decreased to neglectable value only providing a contact of the stylus with the tissue.

A rapid decrease of the depressing force causes a rapid change of mechanical conditions in the tissue, which is then followed by a transition effect of gradual return of the tissue to the initial condition (the deformation response). A similar transition effect follows the depressing of the stylus into the tissue [8].

The deformation response has a character of damped oscillations and is captured through the stylus. Through the analysis of the deformation response it is possible to identify individual components of the response and to consequently approximate the main properties of the reologic model of the tissue. A four-element model with linear elements is supposed in this case [4]. In our case it is possible to recognize changes of the tissue elasticity and of some other characteristics.

Biological characteristics of human skin and its corresponding reologic model are strongly individual and moreover they are variable in time. It is therefore crucial for a measurement in-vivo to mutually compare results of measurements only for the same person and with relatively very small time offset. In this experiment we measure the skin on several places in the disturbed area before and after a therapy, with approximately 30 minutes long time offset.

This measurement method observes relatively quick relaxing effects with duration of several milliseconds to several tenths of milliseconds. The measurement is not directional so that this method cannot be used to observe anisotrophic properties of the tissue.

Matrix identification of a static deformation

The second method identifies properties of a whole region of the explored tissue in a contrast to the first mentioned method, which identifies the properties locally. This method observes much slower relaxing effects then the first mentioned one. A duration of relaxing effects observed by this method is from tenths to hundreds of seconds.

This method is based on an identification of stretchability of a skin and of shiftability of upper skin layers against deeper ones.

A deformation of a skin is in this method identified through an observation of a deformation of a matrix of test marks that are in a relaxed position printed onto skin. The matrix of test marks represents a net of Zener elements. It consists of 24 marks and has a dimensions

60x60 mm. That is also the area of the skin, on which the deformation is observed. After printing the matrix onto the skin, 150 mm long drawing stakes are fixed to the skin along the observed area with a large area sticking tapes. Drawing stakes, when pulled aside produce a homogeneous deformation relatively in the observed area. Then, weights are attached to drawing stakes with strings. The weights become then the sources of deformation force. We have chosen 2kg weights for this experiment, mainly not to cause any pain. The deformation force produced by one drawing stake is thus 20 N. After attaching weights to drawing stakes is then applied the deformation force to the observed area of the skin.

One measurement consists of capturing the matrix state (of positions of individual test marks) before application of the deformation force and after application of the deformation force, after finishing of all transition effects. Matrix states are captured by a camera and mutual displacements of individual test marks are then analyzed graphically and numerically. Changes of mutual distance of test marks are proportional to the local deformation rate. Every examination consists of two measurements, one before and one after a targeted therapeutic treatment.

With this method it is possible to measure an own elasticity of skin as well as its shiftability against subcutis. When a symmetric deformation force is applied to both sides of an observed region then it is possible to observe mostly an own elasticity. With a deformation force applied only to one side of an observed region, mostly a shiftability of skin can be watched, respectively a distribution of deformation in an observed region (e.g. in front of and behind a scar). Both these parameters can be measured in various directions (e.g. along and across a scar) and watch highly anisotrophic properties of skin.

Discusion

The scar is according to the clinical study LEWIT, OLŠANSKÁ [20] one of sources of a myofascial pain and a decreased range of motion, 51 patients suffered from various types of myofascial pain in all sections of the locomotor system. The goal of this study was to prove that throw a well-targeted treatment of a skin with scar it is possible to improve a reduced range of motion and to reduce a pain. All patients were treated by the soft tissue manipulation method [3], making use mainly of the barrier phenomenon [3]. In 36 cases, the scar was proven highly relevant source of the pain and striking results at first treatment and in the course of therapy were achieved. In 13 further cases, the scar was partly relevant, i.e. one of several pathogenic lesions remained after treatment. Only in 3 cases was the scar proven irrelevant as the source of the pain. In the case of a skin with a scar on a chest that is attached to underlying layers is the relation between a skin and a motion system evident.

The treatment of active scars can be of importance in a great number of cases; untreated active scars may often cause a failure of the whole therapy [20].

A care and a treatment of a scar is a necessary part of physiotherapy and it improves a quality live of operated women [18,19]. A scar as a potential source of future complications is currently in a clinical practice not paid enough attention, that attention what we would expect. The expected attention is limited probably due to a fatality of the disease, of the carcinoma of mamma.

One of the possible treatments that can influence a scar already in the early stages is an enzymatic therapy. It improves healing of tissues but currently it is used mainly for patients with a post-surgery lymphoedema [14]. The improvement of healing of scars then utilized only as a side effect and is not used regularly in a clinical practice.

We observe a behavior of scars in-vivo using the described physical methods adapted to particular conditions of this experiment. So far we have successfully tested the first patients with the second mentioned method. There was achieved a 15mm improvement of a skin stretchability in consequence of a physiotherapy. The first mentioned method is still in a development and measurement of healthy tissues. Supposed number of patients for this experiment is 10-15 in this stage and the total period of treatment and measurement for each patient is at least 3 months.

We believe that through the observation and studying of behavior of scars it is possible to learn more about the physical parameters of a skin with scar and their mutual influences.

There are still many not answered questions about scar and how it influences other systems. E.g. it is still not clear whether a scar causes the decreased range of motion through its changed mechanical properties (namely its visco-elasticity) or whether it is only a question of the logistics and perception that are in the surrounding of the operation wound during such destructive operation usually significantly disturbed.

This experiment is still at the beginning so it cannot give an exact and reliable answer to this question but we suppose that the combination of the used measurement methods may help to identify some of processes, which take part in a heeling scar and to consequently apply the results in a clinical practice.

We hope to consequently emphasize the influence of scars to the motor system since various complications and pain appearing even a long time after surgical interventions are very frequented.

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