USE OF ULTRASONOGRAPHY IN EVALUATION OF NEW BONE FORMATION IN PATIENTS TREATED BY THE METHOD OF ILIZAROV

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Abstract: Background: Lengthening of bones by gradually distracting bone fragments using an external apparatus by Ilizarov, is a long process with numerous complications. The greatest threats in limb lengthening are poor new bone formation as well as premature consolidation of the newly generated bone. The purpose of this study was to determine the importance of ultrasonography in evaluation of bone formation in limb lengthening.

Patients and Methods: The study involved 31 patients, in whom 52 long bones were lengthened by the Ilizarov method at the University Clinic for Orthopaedic Surgery in Skopje from 2006 to 2010. The study revealed the results of ultrasonographic analysis of new bone formation at four various stages of limb lengthening. The analysis of the results of ultrasonographic examination of bones throughout the lengthening process was based on the form and dimensions of the obtained ultrasonographic parameters – indicators of new bone formation – as well as on the appearance of the cortical margin at the distraction site.

Results: Tiny, solitary and confluent hypo-echogenic foci developed on sonograms approximately 2 weeks after distraction was commenced. At stage I a new cortical margin was detected in 30.77%. The number of initial small indicators significantly decreased throughout lengthening. At stage IV the solitary indicators rate was 9.51%, whereas the linear indicators rate significantly increased from 22.12% at the first stage to 54.3% at the last stage. the cortical margin was presented in all 52 bones at III and IV stage of lengthening.

Discussion and Conclusions: Ultrasonography enabled an evaluation of the degree of new bone formation and it preceded the radiographic changes at the distrac-
tion site. This helped to determine the surgical lengthening and to avoid numerous complications.

**Key words:** Limb lengthening, new bone formation, ultrasonography.

**Introduction**

Bringing up to date the method of strain of tension by Ilizarov in the 50-ties of the 20th century, means a great scientific advance in the gradual lengthening and correction of deformities of extremities. Using his external ring-apparatus and tensioned wires transfixing the bone, he especially concentrates his attention upon the corticotomy as a method of cutting the bone tissue which means a method of preserving the intramedullary blood supply during the surgical lengthening and correction of deformities of the limbs. [1–3] Lengthening a long bone by cutting it surgically and then pulling apart the bone fragments using the method of "strain of tension" is a process laden with numerous complications. [4–6] The greatest threats in new bone formation at the distraction site are either poor bone consolidation and remodelling of the newly generated bone or its premature healing, both due to an inadequate rate, frequency or rhythm of surgical distraction. This can lead to fractures, distortion of the axis, or lack of osseous consolidation around the newly formed bone. [7, 8] Therefore, a permanent monitoring of the entire process is necessary, from the moment treatment is commenced, until the distraction apparatus is removed. In the last two decades of the 20th century, the first experiences with regard to use of some diagnostic methods different of native radiography in detecting changes at the distraction site have been reported (ultrasonography, DEXA). [9] This study presents an ultrasonographic analysis of new bone formation in surgically lengthened bones in patients treated by the method of Ilizarov. The purpose is to determine the usefulness of ultrasonography in evaluation of the changes between the bone fragments that are gradually pulled apart at various stages of lengthening of long bones.

**Material and methods**

31 patients treated by the method of Ilizarov at the Clinic for Orthopaedic Surgery in Skopje in the time period from 2006 to 2010 were ultrasonographically examined on 32 segments throughout the lengthening process. 17 of them were with congenital, 6 with developmental disorders, 5 with trauma, 2 with obstetric hemiparesis and 1 with neurofibromatosis. 15 of the patients were male and 16 female. The mean age of the patients was 21 years and they were statistically divided into three age groups: 5–18, 19–29 and over 30 years of age. 21 of the patients were in the age group from 5–18, 3 of them in the group from 19 to 29 years of age, and 7 in the group over 30 years of age. The 32
lengthening segments were as follows: 20 lower legs, 8 thighs, 3 forearms and 1 upper arm. 52 bones underwent corticotomy and gradual lengthening from which 20 tibias, 18 fibulas, 8 femurs, 3 ulnas, 2 radiuses and 1 humerus, were analysed in 4 different stages of the lengthening process:

1. Stage of corticotomy and early lengthening of the segment;
2. Stage of advanced lengthening and strain of tension of the segment;
3. Stage of mineralization and bone consolidation;
4. Stage of bone remodeling.

The lengthening rate was 1 mm/day, the mean lengthening 59 mm.

Ultrasonographic examinations were performed using linear transducer (7,5 MHz) at the corticotomy site in longitudinal and transversal plane simultaneously in each stage of the lengthening process separately, till the moment of removal of the external apparatus. Radiographic analysis on the same patients and segments was made too, simultaneously with ultrasonographic examination.

According to the form the ultrasonographic parameters of new bone formation were presented as three modalities: solitary, confluent and linear parameters of new bone formation, each of them typical for a different lengthening stage. The rate of each modality was estimated in all lengthening stages separately.

According to the dimension the parameters were divided in three groups as well: parameters smaller than 5 mm in diameter, from 5 to 10 mm, and over 10 mm in diameter.

The appearance of cortical margin was analysed through the number and the rate of examined bones in which a cortical margin was visible on the sonograms compared to the whole number of examined bones. Analysis was made in each lengthening stage separately.

Results

In the first weeks of the examination in the distraction gap, the sonograms presented a well defined defect in the cortical bone, with dominant presence of tiny, solitary and confluent hypoechogenous indicators of new-bone formation, arranged in an irregular, even chaotic manner. The transverse images had a speckled appearance similar to a multifilament wire cut in a cross section. First elements of new bone formation, differing in morphology, density and structure were detected in a time period from 2 to 4 weeks postoperatively, which on our clinical material, preceded the first radiographic detection by approximately 4–6 weeks. Along with increasing of number, dimensions and intensity of the sonographic parameters of new bone formation, especially in patients with more rapid generating of new bone, there was an obvious coalescence of the parameters into longitudinal indicators of new bone, which were
orientated in the direction of the longitudinal artificial strain of tension on the lengthened segment. (Figure 1)

![Ultrasonographic detection of tiny, solitary, confluent and linear indicators of NBF in first stages of lengthening](image)

**Figure 1** – Ultrasonographic detection of tiny, solitary, confluent and linear indicators of NBF in first stages of lengthening

The average distribution of each of the three defined modalities of form (solitary, confluent and linear sonographic parameters of new bone formation) compared with the other two for every stage of lengthening process separately is presented in Figure 2. There is an obvious decreasing of the solitary and confluent indicators rate throughout the lengthening process (especially the solitary focuses of new bone formation), whereas the rate of the linear sonographic parameters increases gradually (54.3% at the last stage of lengthening).

![The average distribution of each of the three defined modalities of form in four lengthening stages](image)

**Figure 2** – The average distribution of each of the three defined modalities of form in four lengthening stages

The average distribution of sonographic parameters within each of the three defined dimension groups (parameters smaller than 5 mm in diameter, from 5 to 10 mm, and over 10 mm in diameter) compared with the other two for
every stage of lengthening process separately, is presented in Figure 3. Results reveal a high percentage of parameters smaller than 5 mm in diameter in all stages of lengthening and a minor distribution rate of the parameters over 10 mm in diameter.

Figure 3 – The average distribution of each of the three dimension groups of parameters in the lengthening process

In addition, an appearance of a cortical margin became obvious in the first 6–8 weeks after the surgical procedure with slight central invagination and far smaller thickness in comparison with the surrounding cortical structure. The number and the rate of examined bones in which a cortical margin was visible on the sonograms compared to the whole number of examined bones is presented in Figure 4.

Figure 4 – The rate of examined bones with a visible cortical margin on the sonograms at different lengthening stages

At this lengthening stage, in two patients a "cystic regenerate" was detected on sonograms with no parallel visualization on X-rays.
The appearance of a hyper-echogenous cortical line in the longitudinal plane and a hyper-reflecting solid line in the transverse plane on the sonograms determined the stages of bone consolidation and remodelling. From this point, the diagnostic value of ultrasonography in evaluation of NBF was decreasing till the end of lengthening, whereas radiography became the method of choice in detecting the morphological, structural and density changes of bone indicators at the last 2 lengthening stages. (Figure 5)
Discussion

The method of strain of tension (MST) gives the basis of slow and gradual distraction of biological tissues including their metabolic activation, which gives as a result an increase in proliferative and biosynthetic processes in the lengthened extremities. The dynamics of these events depends on the blood flow in the lengthened tissues, the stimulating effect of the mechanical strain of tension as well as on the functional capacity of the treated segment. The extent of new bone formation depends on many biological and mechanical factors having an obvious influence on the response of the segment, e.g. of the lengthened extremity. Some of them are minimal disturbance of bone, delay before distraction, rate and rhythm of distraction, site of corticotomy, number of lengthening sites, etc.

Radiological methods have been proven mandatory in the examination of bone and surrounding soft tissues in surgical lengthening and correction of deformities of extremities. In the last twenty years of the last century, the first experiences using some other diagnostic methods in detecting changes at the distraction site were reported (ultrasonography, osteodensitometry). [10, 11] This study presents an ultrasonographic analysis of new bone formation in surgically lengthened bones in patients treated by the method of Ilizarov in order to determine the diagnostic value of ultrasonography in the evaluation of the changes between the corticotomized bone fragments at 4 separate stages of the lengthening of long bones.

Ultrasonographic analysis of the indicators of newly generated bone from the point of view of their form (solitary, confluent and linear) has presented a significant decrease in the average rate of solitary focuses of new bone formation as well as an obvious increase of linear focuses throughout the lengthening process, whereas the group of confluent indicators of new bone formation has shown a rather even distribution of values in all of the lengthening stages. Therefore, the confluent indicators in this study could be sonographically clearly detected even in the remodelling stage, visualization which might be impossible to achieve using other diagnostic methods such as native radiography.

Ultrasonographic analysis of the indicators of newly generated bone from the point of view of their dimensions (smaller than 5 mm, 5–10 mm and over 10 mm in diameter) has presented an even distribution of the average values of each modality within that grading system in all of the 4 lengthening stages. Over 85% of focuses throughout the whole lengthening process belong to the group of focuses smaller than 5 mm which indicates some limited possibilities of the sonographic method in visualization of larger indicators of newly generated bone from the start till the end of the lengthening process.

The an analysis of the appearance of the cortical margin at the distraction site in all of the 52 examined bones has presented an expected increase at the rate of 30, 77% at stage I to 100% at the end of lengthening. The rather high percentage of appearance of the cortical margin at the beginning of the lengthening process, has been confirmed in some of the references in the literature [12].
An appearance of so-called cystic regenerate means a sort of crisis in the process of bone mineralization as well as in the remodelling stage, but moreover it means a significant change in the physical and mechanical properties of the newly generated bone. Ultrasonography is very important in detecting "cystic regenerate" in the early lengthening stages when it might be impossible to receive any similar information using other diagnostic methods. [13, 14] Native radiography has been proven mandatory in bone visualization at the last two stages of bone lengthening e.g. consolidation as well as the bone remodelling stage. [15] However, using native radiography and ultrasonography in the evaluation of new bone formation at the distraction site often resulted in premature removal of the fixator after a lengthening procedure with gradual bending or acute fracture of the newly formed bone. Therefore, using some additional quantitative methods during the consolidation and remodelling stage of lengthening (DEXA, Q-CT) has decreased the rate of fractures while maintaining an acceptable bone healing index without excessively increasing fixation time [15, 16].

Conclusions

Ultrasonography is superior in detecting initial indicators such as solitary and confluent focuses, as well as tiny indicators smaller than 5 mm in diameter throughout the whole lengthening process. The first elements of new bone formation appearing on sonograms 2–4 weeks prior to their radiographic detection, as well as significantly earlier sonographic detection of the cortical margin compared with the native radiographs, clearly outline the advantage of the ultrasonographic method towards the early visualization of the bone precursors at the distraction site.

Ultrasonographic examination has a significant influence on the dynamics of surgical lengthening as a determination method of rate, frequency and rhythm of mechanical strain of tension of the segment. The ultrasonographic and radiographic results at the remodelling stage are important in the evaluation of mechanical stability of the newly produced bone. Combined with some of the quantitative methods of evaluation of new bone formation they are useful in determining the final moment of removal of the external frame from the lengthened segment.

REFERENCES

1. Ilizarov AG. Results of clinical tests, an experience obtained from the clinical use of the set of Ilizarov compression-distraction apparatus. Med. Export, Moscow, 1976.


Резиме

КОРИСТЕЊЕ НА УЛТРАСОНОГРАФИЈАТА ВО ЕВАЛУАЦИЈАТА НА НОВИТЕ КОСКЕНИ ФОРМАЦИИ КАЈ ПАЦИЕНТИТЕ ТРЕТИРАНИ СО МЕТОДОТ НА ИЛИЗАРОВ

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Апстракт: Основа: Продолжување на коските со постепено одделување фрагменти од коските со користење надворешна апаратура Илизаров, е долг про-

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цес со бројни компликации. Најголемите закани во издолжувањето на екстремитетите се сиромашните нови коскени формацији, како и предвремена консолидација на новогенерираната коска. Целта на оваа студија беше да се утврди значењето на ултрасонографијата во евалуација на коскената формација во издолжувањето на екстремитетите.

Пациенти и методи: Студијата вклучи 31 пациент, кај кои 52 долги коски беа издолжени со методот Илизаров на Универзитетската клиника за ортопедска хирургија во Скопје од 2006 до 2010. Студијата ги открива резултатите од ултрасонографската анализа на новата коскена формација на четири различни фази на издолжување на екстремитет. Анализата на резултатите од ултрасонографското испитување на коските во текот на процесот на продлажување беше заснована на формата и димензиите на добиените ултрасонографски параметри – индикатори на новата коскена формација – како и на појавата на кортикална маргина на местото на одделување.

Резултати: Мали, осамени и конфлуентни на хипохогенски фокуси развиени на сонограми околу 2 недели по започнувањето на одделувањето. Во фазата I беше открена нова кортикална маргина во 30,77%. Бројот на првичните мали индикатори значително се намали во текот на издолжувањето. Во фазата IV стапката на осамените индикатори беше 9,51%, додека стапката на линеарните индикатори значително се зголеми од 22,12% во првата фаза на 54,3% во последната фаза. Кортикалната маргина беше претставена во сите 52 коски во III и IV фаза на издолжувањето.

Дискусија и заклучоци: Ултрасонографијата овозможи евалуација на степенот на новата коскена формација и таа им претходеше на радиографските проучвания на местото на одделување. Ова помогна да се утврди хируршкото издолжување и да се избегнат бројните компликации.

Ключни зборови: издолжување екстремитети, нова коскена формација, ултрасонографија.

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