Capsular expansion after ultrasound-guided injection of the hip as parameter of efficacy: description of technique and report of preliminary data

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Abstract

The infiltration procedure with hyaluronic acid has proven to be effective and safe in the integrated multimodal therapy of hip osteoarthritis. Ultrasound represents a diagnostic and therapeutic support to the infiltration procedure; it is hence possible to carry out an appropriate study of the hip in the pre-infiltration phase. Through ultrasound-guiding, the infiltration therapy can be performed with precision, safety, and maximum comfort for the patient. Ultrasound imaging allows us to study the capsular space and the identification of the capsular line, and after the introduction of hyaluronic acid, the capsular expansion of the hip can be a parameter of treatment efficacy.

This study evaluates the extent of capsular expansion of the hip in ultrasound after infiltration therapy and its correlation with a positive outcome.

Introduction

Ultrasound guided visco-supplementation has proven to be effective and safe in the integrated multimodal therapy of hip osteoarthritis. Through ultrasound-guidance, the injection therapy can be performed with precision, safety, and maximum comfort for the patient. Ultrasound imaging allows us to study the capsular space in the pre-infiltration phase and, after the introduction of hyaluronic acid, the capsular expansion of the hip can be evaluated. Capsular expansion (CE) of the hip could be considered as a parameter of treatment efficacy.[1-4]

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Materials and Methods

Objective of the study

The goal of the study is to establish the clinical validity of the systematic measurement of capsular space, capsular expansion and its variations, after viscosupplementation of the hip.

Anatomical characteristics of the articular space

The measurement of the capsular space at baseline is indicative of the state of the joint capsule. By the abduction and extra-rotation maneuver it is possible to to have a dynamic ultrasound evaluation of the extent of capsular expansion. CE during the infiltration treatment, intended as an increase in volume of the capsule with relaxation of its fibers and consequent increase in the intra-capsular pressure, is dependent on the integrity of the capsular fibers themselves, the acetabular labrum, the orbicular area and the transverse acetabular ligament.

Pathological joint capsules in patients with hip osteoarthritis or femoral-acetabular impingement are thicker than the normal joint capsules.[5] A study carried out *in-vivo*, intra-operatively, in patients who were about to undergo hip replacement, showed that severe osteoarthritis was constantly associated with lower intracapsular pressure and less elasticity of the joint capsule.[6] The volumetric capsular transitions, induced by the infiltration therapy, indicate the elasticity of the joint capsule and of the orbicular area. The volumetric capsular transitions, induced by the infiltrative therapy, expression of the elasticity of the articular capsule and the orbicular area, could give back movement to the liquid after the stance phase of the step favoring the synovial circulation of the hip.[7]

The acetabular labrum acts as a gasket and controls synovial fluid distribution. It is the valve that determines the transfer of the synovial fluid from the central compartment. When injured, the normal circulation of the synovial fluid is affected, thus exposing the joint to early degenerative processes.[8] The physiological sealing characteristics of the synovial fluid exerted by an intact acetabular labrum cannot be reproduced after labrum repair or reconstruction surgery.[9] The acetabular labrum has free nerve endings and sensitive corpuscles that are compatible with the perception of pain in case of lesion, and with a proprioceptive function. A labial lesion is clinically symptomatic and is visible on ultrasound. The orbicular zone (ZO) acts as a ring that resists the distraction of the femoral head

and contributes to the dynamic circulation of the synovial fluid.[10]

Also, the transverse acetabular ligament has the characteristics of a valve.[12] Arthroscopic observations have found that during the phases of flexo-extension hip there is a sort of *portcullis* effect made by the transverse ligament which moves away or crushes on the femoral neck during the movements of the latter. In the oscillating phase of the step, characterized by a negative pressure gradient, the synovial fluid enters the central chamber (assuming it enters from the antero-inferior acetabular region, near the transverse acetabular ligament). It is probable that the ZO could maximize the effects of the negative gradient through its fibrous annular structure by limiting the volume of the proximal portion of the peripheral compartment, compensating for sudden pressure drops. Then later, in the stance phase, the valve system opposes its reflux by stabilizing the pressure regimes in the central compartment. These data suggest the importance of the different anatomical structures of the hip joint, their influence, the need for their integrity and their role in the detection of the ultrasound parameter of capsular expansion.

In common clinical practice, it is necessary to bear in mind the physiological features that must be preserved to ensure the alternation of pressure between the peripheral and the central compartments. Hip osteoarthritis alters the functionality of the hip, and consequently, the circulation of the synovial fluid is involved in the pathological process. The pressure gradients of the hip compartments and the circulation of the synovial fluid are compromised and insufficient in case of lameness and rigidity, the measurement of capsular expansion, the baseline and after infiltration therapy-would be an expression of the capsular volumetric transitions, determined by the elasticity of the joint capsule and the orbicular area that restore movement to the liquid after the supporting phase of the step, favoring synovial circulation of the hip.[11-13]

Description of capsular expansion evaluation

The capsular expansion (CE) is an imaging parameter that can be obtained during an ultrasound-guided infiltration procedure of the hip. It is the effect caused by the introduction of hyaluronic acid (HA) inside the hip's joint capsule. The capsular space (CS), measured at baseline, results from the average of three measurements.

This space is delimited by the bone profile of the femoral head (FH) distally, the articular line, the joint line (JL) and by the line that delimits proximally the joint capsule, the capsular line (CL), below the iliopsoas muscle. The transition area, *i.e.* the white line between the joint capsule and the psoas muscle with its tendon is identified as the joint capsule reference line, called the capsular ultrasound reference line (Figure 1).

The measurements of the capsule, and subsequently, of the expansion are performed from the JL to the capsular ultrasound reference line, in the middle cervical area and, laterally, in a specular way. The average of the three measurements is the value of the capsular space (basal) and the capsular expansion (after injection).

The anterior ultrasound study of the hip follows the criteria of the systematic analysis and also includes the visualization of the vessels (color), the iliopsoas with its bag, the acetabular labrum and the power doppler function during the pre-infiltration phase. During the procedure, the needle trajectory is checked by ultrasound scanning (Figure 2).

The post-injection phase (Figure 3) is dedicated to the evaluation of the CE after passive mobilization (Figure 4) of the hip. US imaging offers a *real-time* and dynamic assessment of the hip CE. The CE, induced by the introduction of HA, reflects the volumetric increase of the capsule with the relaxation of its fibers and consequent increase in intracapsular pressure. The resulting effect is joint expansibility. The CE and its variations could also have positive repercussions on the circulation of the synovial fluid inside the joint.

Results

Preliminary studies were conducted on patients suffering from hip osteoarthritis treated by ultrasound-guided infiltration therapy with hyaluronic acid (linear HA medium molecular weight, >2000 kDa/2 mL). 40 patients with hip osteoarthritis, grade II-IV Kellgren and Lawrence, were enrolled in the first study. 20 patients were treated with 3 ultrasound-guided intra-articular HA injections in the hip weekly. 20 patients, grade II-IV Kellgren and Lawrence, were treated with a cycle of 2 injections weekly. Linear HA with molecular weight >2000 kDa was used in both groups. The amount per single injection was 2 ml. Samsung HM70A ultrasound with 1-7 MHz convex probe and 7.5 MHz linear probe, and ALOKA Prosound 3.500 ultrasound using 3-5 MHz convex probe and 7.5 MHz linear probe and Mindray TE 5 ultrasound with 7.5 MHz linear probe were used.

The first group of patients responded favorably to the treatment

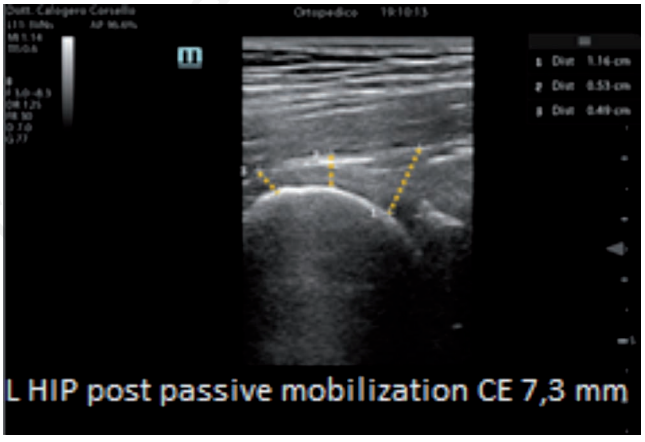

Figure 1. Capsular ultrasound reference line (CURL), dotted line.

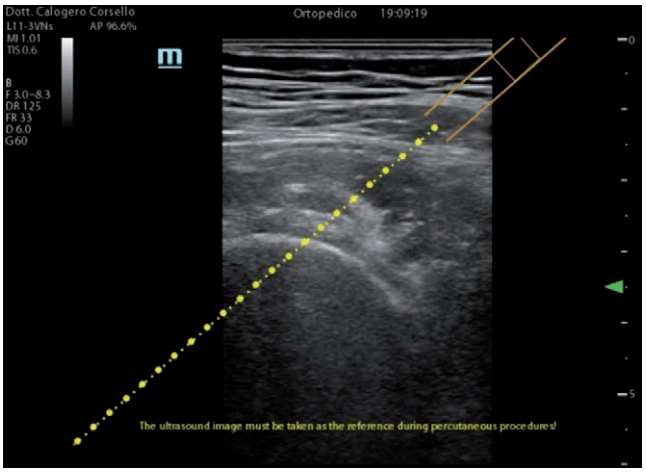

Figure 2. Ultrasound procedure, biopsy guide.

with improvement of joint pain and functionality correlated with the CE, which in turn correlates directly with the recovery of the range of motion (ROM) of the joint. The restoration of expansibility through intra-articular injection with HA should recreate the normal intracapsular pressure gradients and the physiological circulation of the synovial fluid.[12]

In the second group of patients, joint stiffness, assessed with the simplified sub-scale WOMAC, decreased after VS. The improvement in hip joint ROM was significant in cases where the CE, after injection with HA, was greater than 25% or 50% compared to the ultrasound measurement of the basal capsular space.

Patients who started hip mobilization early based on the positive expansibility showed greater joint recovery. Moreover, patients underwent physiokinesitherapy with active assisted kinesis, and manual stretching of the hip was immediately undertaken to reduce joint stiffness. The reduction of stiffness led to a decrease in painful symptoms, the resolution of any extra-rotation of the lower limb, and an increase in capsular expansion.

In hip osteoarthritis, two intra-articular, ultrasound-guided injections with HA lead to a result in terms capsular expansibility that is similar to an infiltration treatment based on three weekly injections.

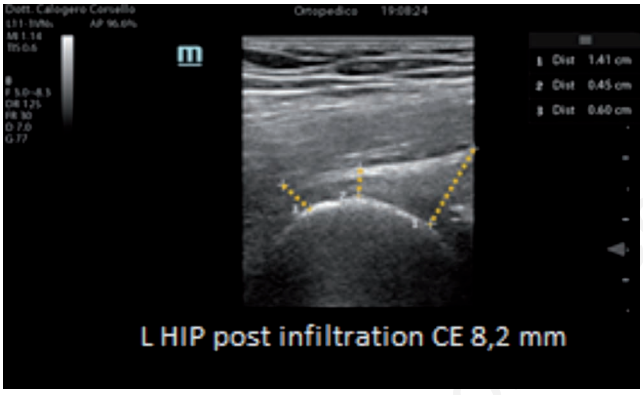

Figure 3. Ultrasound procedure, post-injection phase.

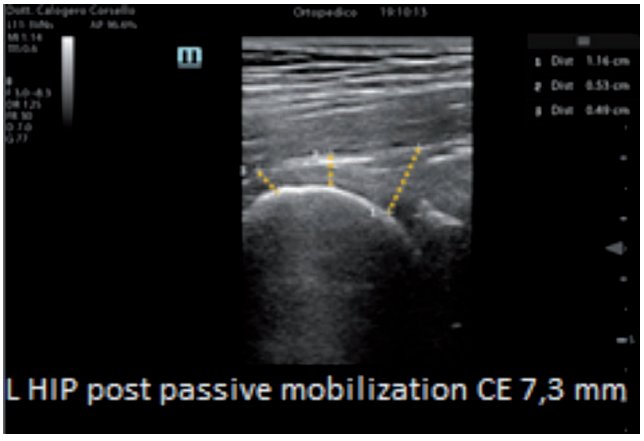

Figure 4. Ultrasound procedure, measurement CE post passive mobilization.

Discussion

Untreated inflammation in the acute stages is believed to evolve into the chronic stages of capsular fibrosis, some authors have compared this process to that of adhesive capsulitis of the shoulder.

After HA injections, CE can be studied as a prognostic index of hip function recovery. Capsular expansion is a reproducible and comparable ultrasound datapoint.

The detection of the capsular expansion requires a systematic and precise ultrasound study as well as a thorough clinical examination of the patient in order to make an accurate diagnosis and plan the infiltration therapy.

A labral lesion, appreciable ultrasonographically, must be constantly checked. The infiltrative therapy, in case of concomitant lesion of the acetabular labrum, is ineffective and should not be performed. Constant ultrasound measurement of the hip capsular space provides comparable numerical parameters. In clinical practice patients appreciate this monitoring.

The short-term follow-up (*i.e.* 1 month after the infiltration cycle) of our data confirmed that the CE could be an index of hip function recovery. After the first injection, the measurement of the CE correlated with the state of the joint capsule and other related structures. The CE data can be obtained in real-time during the infiltration procedure, are reproducible and comparable. This means that, during the infiltration procedure, the expansibility data allows an immediate perception of the response of the capsule to the introduction of the HA. Then, the comparison of measurements at baseline and post-injection highlighted the state of expansion, maintenance and comparison to baseline. The data can be related to the state of the hip joint and secondarily to pain and the possible use of analgesics.

The capsular expansion analysis must be carried out at all stages of the procedure. The measurement of the capsular space could act as a surrogate of efficacy and can help in the follow-up and to choose wisely the kind, volume and concentration of HA to inject. The post-infiltrative ultrasound study, with the measurements of the capsular space, repeated at regular intervals and compared with the radiographic measurements of the joint space, the clinical parameters of functionality and the pain scales allows to evaluate the effectiveness of the procedure. Moreover, CE post infiltrative values can be correlated with other clinical parameters.

The ultrasound guidance, indispensable for a correct infiltration treatment of the hip, allows to detect the capsular space, measure the capsular expansion after the introduction of HA and its variations. The ultrasound can highlight a cartilage alteration that can be investigated with radiographic examination. Using an ultrasound study, it is possible to visualize the acetabular labrum, also *dynamically*, in order to detect lesions of the labrum which would reduce the effectiveness of infiltration therapy by compromising the *seal* function of the joint. It is possible with appropriate maneuvers to view the distensibility of the capsular fibers in the pre-injection phase by planning the quantity and type of HA to be injected.

CE detected by ultrasound during hip injection represents a numerical value and a percentage variation that defines a *relatively* constant characteristic of a population of patients affected by a degenerative hip disease treated with a precise therapeutic procedure. This value makes it possible to identify *responders* to hip infiltration therapy with HA.

The limitations of this research are: i) limited observation sample; ii) experimental study with limited literature on the topic; iii) analyses not conducted through control groups.

Gait analysis studies show that the parameters related to walking speed in patients with untreated hip osteoarthritis are slower due to painful walking, the need for pain control and the coexistence muscle hypotrophy. After hip viscosupplementation with HA, the joint shows an improvement in the temporal, kinetic and kinematic parameters associated with pain reduction. Several authors have reported a clinical improvement, characterized by a significant change in the gait model after intra-articular therapy with HA.[4-6] We are currently conducting a multicentric study on patients with hip OA to correlate the results of the Gait Analysis, obtained with the BTS G Walk device, with the values of the capsular expansion detected by ultrasound after VS. Another ongoing study is aimed at calculating the volume of the joint capsule starting from the ultrasound values of the capsular space and would verify the correlation between capsular expansion and changes in the capsular volume.

The joint expansion of the hip joint capsule can be interpreted as the outcome of inflammatory states of the capsule or an index of elasticity of the joint capsule and joint functional recovery. This space is delimited by the bone profile of the femoral head (FH) distally, the articular line, the joint line (JL) and by the line that delimits proximally the joint capsule, the capsular line (CL), below the iliopsoas muscle. The transition area, *i.e.* the white line between the joint capsule and the psoas muscle with its tendon is identified as the joint capsule reference line, called the capsular ultrasound reference line (Figure 1).

Our results outline the concept of capsular expansion intended as a volumetric increase of the capsule with relaxation of its fibers and consequent increase in intracapsular pressure. This preliminary data suggest the clinical usefulness of detecting capsular expansion by ultrasound to predict the effectiveness of infiltration therapy. Further studies in this area on a large cohort of patients will further improve the specificity of this parameter.

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