PATIENT SELECTION AND OPTIMISING OUTCOME IN HIP ARTHROSCOPY

NIELS BECH

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STELLINGEN

1. Obesitas is een relatieve contra-indicatie voor een heup arthroscopie. *Dit proefschrift*

2. Standaard hechten van het heupkapsel bij alle patiënten na een heup arthroscopie leidt niet tot betere resultaten en niet tot beter continuïteit herstel van het kapsel. *Dit proefschrift*

3. Postoperatieve pijnbehandeling na een heup arthroscopie dient geïndividualiseerd en multimodaal te zijn. *Dit proefschrift*

4. Geen lokale anesthesie techniek of perifere zenuwblokkade is aantoonbaar beter dan de ander als postoperatieve pijnbehandeling na een heup arthroscopie. *Dit proefschrift*

5. Zowel de Pain Catastrophizing Scale als de Central Sensitization Index zijn tools bij het identificeren van patiënten met een verhoogd risico op hogere postoperatieve pijn na een heup arthroscopie. *Dit proefschrift*

6. Subspine, ischiofemorale en pelvitrochanteric impingement zijn bijzondere vormen van heup impingement en vereisen een specifieke diagnostiek en chirurgische behandeling. *Dit proefschrift*

7. Het lichaam is dom, het kan maar op 1 plek pijn voelen.

8. "No one gives it to you. You have to take it." *Frank Costello*

9. Punten naar het dal, bochten zijn voor watjes.

10. "I'm gone. I'm dead." *Tadej Pogacar*

N I E L S B E C H

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Chapter 1

GENERAL INTRODUCTION

Although hip arthroscopy has been performed for several decades now, it is still a relatively new phenomenon in orthopedic surgery that is not as commonly practiced as knee or shoulder arthroscopy but is slowly establishing its place in orthopedics. This could be because it can be considered a challenging surgery since the hip joint is not easily accessible but also because indications and outcomes are not as well established as for the other large joints.

Recent improvements in arthroscopic techniques and imaging modalities and a better understanding of hip complaints in young patients (<50 years) now make hip arthroscopy a powerful tool to treat young patients with both intra- and extra-articular hip pathologies. The recognition of femoral acetabular impingement syndrome (FAIS) as a cause of hip pain gave hip arthroscopy a boost and is one of the reasons that the procedure became more popular in recent decades. Registry studies show that the number of performed hip arthroscopies continued to increase between 2005 and 2014 [1–3]. But reached a plateau after 2015.

With hip arthroscopy gradually finding its place in orthopedics, the number of published articles on the matter has increased, but some questions remain. This thesis aims to answer several questions regarding patient selection for and outcome optimisation after hip arthroscopy.

HIP ANATOMY

The hip joint is a multiaxial joint, and rotational movement is possible in 3 planes. In the sagittal plane, it is flexion-extension; in the coronal plane, it is abduction-adduction; and in the transverse plane, it is internal rotation-external rotation. Stability in the hip joint mainly arises from the bony architecture of the joint, the acetabular labrum and the surrounding hip capsule and capsular ligaments (figure 1) [4].

The capsule of the hip consists of the following ligaments: iliofemoral ligament (or ligament of Bigelow), pubofemoral ligament, ischiofemoral ligament and the zona orbicularis (figure 2). The iliofemoral ligament lies anteriorly of the hip and is the strongest of these ligaments; it tightens the hip in extension and during external rotation. The pubofemoral ligament lies inferiorly and medially and tightens the hip in extension and abduction. The ischiofemoral ligament lies posteriorly and tightens the hip joint during flexion and internal rotation [5]

In addition to these 3 ligaments, the zona orbicularis (or annular ligament) which acts as a locking ring around the neck of the femur and resists in distraction forces of the hip [6].

The labrum of the hip is a triangular fibrocartilaginous structure that attaches to the bony rim of the acetabulum. The labrum increases the acetabular volume and acts as a stabilizer of the hip joint [7]. In patients with dysplasia of the hip there is less stability from the bony architecture, which leads to an increased load and strain on the labrum that possibly results in labral tears or labral disruption of the bony rim [8].

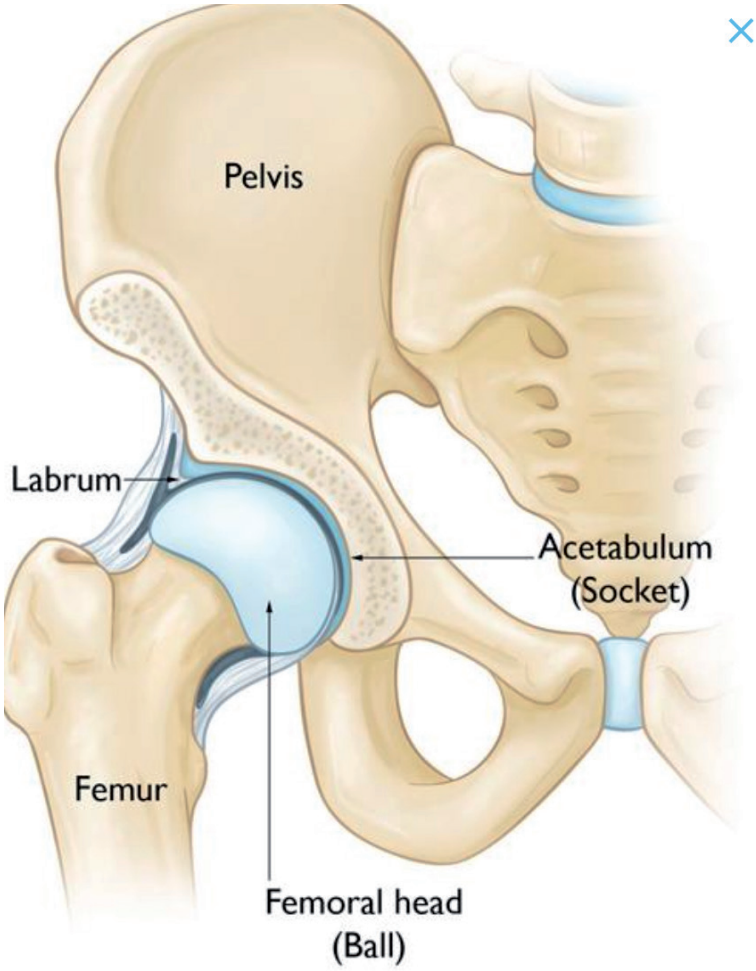

Figure 1: *A normal hip joint seen from anterior (Reproduced with permission: OrthoInfo. (c) American Academy of Orthopaedic Surgeons. https://orthoinfo.org/)*

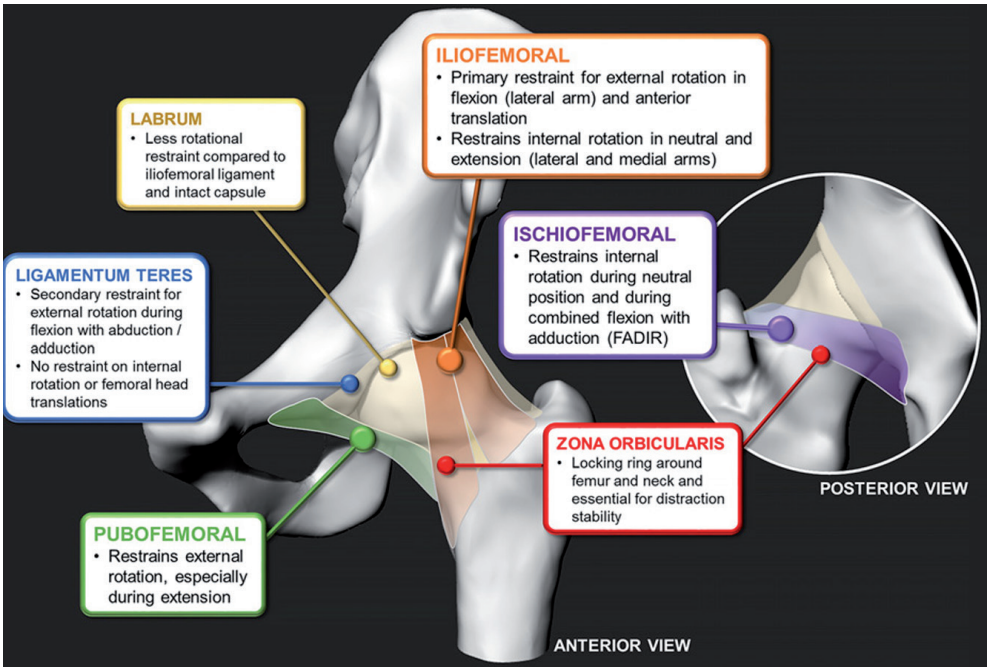

Figure 2: *The capsule of the hip shown from anterior and posterior (reprint with permission [5])*

FEMOROACETABULAR IMPINGEMENT SYNDROME (FAIS)

Femoroacetabular Impingement (FAI) occurs when there is contact between the acetabulum and femur. FAI is usually caused by an abnormal shape or orientation of the acetabular socket or the presence of excessive bone on the head-neck junction of the femur. Although anatomical studies already mentioned FAI in the nineteenth century it was the publication by Ganz et al in 1991 that led to an increased attention to the topic [9,10]. There are 3 main types of impingement; cam, pincer and a combined (mixed) type (figure 3).

FAI is not always symptomatic; a review by Frank et al showed that in asymptomatic patients 37% had a cam deformity and 67% had a pincer deformity [11]. In patients with FAI, the repetitive abutment can lead to reduced range of motion and associated hip pain, in these symptomatic patients it's called Femoroacetabular Impingement Syndrome (FAIS).

In 2016 the Warwick agreement on FAIS was published after an international consensus meeting [12]. The agreement states that FAIS is a motion-related clinical disorder of the hip with several symptoms, clinical signs and imaging findings. It represents symptomatic contact between the acetabulum and proximal femur. The primary symptom of FAIS is

motion-related or position-related pain in the hip or groin. The pain can also be felt in the back, the buttock or thigh. Clicking, locking, stiffness, restricted range of motion or giving way of the hip are also described.

CAM IMPINGEMENT

Ganz et al postulated abnormal contact between the acetabular rim and the femoral head-neck junction in several patients. In the paper by Ganz et al this increased contact was caused by posttraumatic changes and posttraumatic deformity after a femoral neck fracture, and the deformity was called a cam deformity. In patients with a cam deformity, it can be said that the femoral head/neck junction is not a smooth round shape and cannot rotate smoothly in the acetabular socket (figure 3). The repetitive abutment between the cam deformity and the acetabular rim during (rotational) movement can lead to labrum tears, cartilage damage and earlier development of arthritis of the hip [13]. A cam deformity is more prevalent in the athletic population, and is also more seen in men than women [11].

There are some reasons why patients form a cam deformity. One reason is that patients have a posttraumatic deformity after a femoral neck fracture (as described by Ganz) but the deformity can also be caused by childhood hip diseases such as slipped capital femoral epiphysis (SCFE) or Legg-Calve-Perthes [14,15].

However, there is also a high number of young and active patients with a cam deformity who did not have a history of previous hip disease or hip fracture [16]. A relatively new hypothesis why this group of patients forms a cam deformity is because of repetitive excessive femoral loading on the femoral growth plate during skeletal maturation, mainly due to physical activity, especially high-impact sports such as football, basketball or ice-hockey (figure 4) [16,17].

PINCER IMPINGEMENT

The other main form of impingement is pincer-type impingement. In patients with pincer impingement, there is overcoverage on the acetabular side (and no deformity of the femoral head/neck junction). Pincer deformities are more prevalent in women than in men [18].

Pincer is mainly seen in patients with retroversion of the acetabulum. The normal orientation (version) of the acetabulum is approximately 17 ± 6 degrees of anteversion measured in the axial plane (figure 5) [19]. If the orientation of the acetabulum is posterior it is called retroversion and it is a possible cause of pincer impingement.

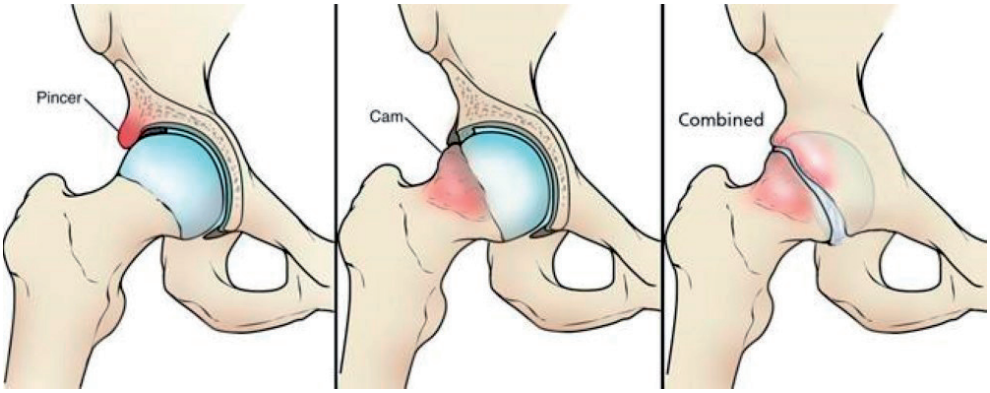

Figure 3: *Types of impingement: pincer impingement with overcoverage on the acetabular side. Cam impingement with a deformity of the head-neck junction and a combined type with both a pincer and cam component (Reproduced with permission: OrthoInfo. (c) American Academy of Orthopaedic Surgeons. https://orthoinfo.org/)*

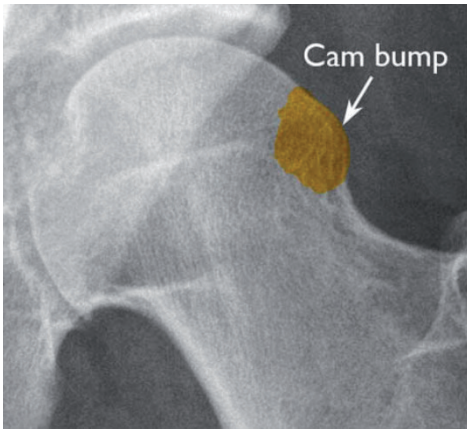

Figure 4: *X-ray shows a CAM bump on the femoral head (Reproduced with permission: Diaz-Ledezma C, Higuera CA, Parvizi J: Mini-open approach for the treatment of FAI in Sierra RJ (ed); Femoroacetabular Impingement. Rosemont, IL. American Academy of Orthopaedic Surgeons, 2013. 81-91.)*

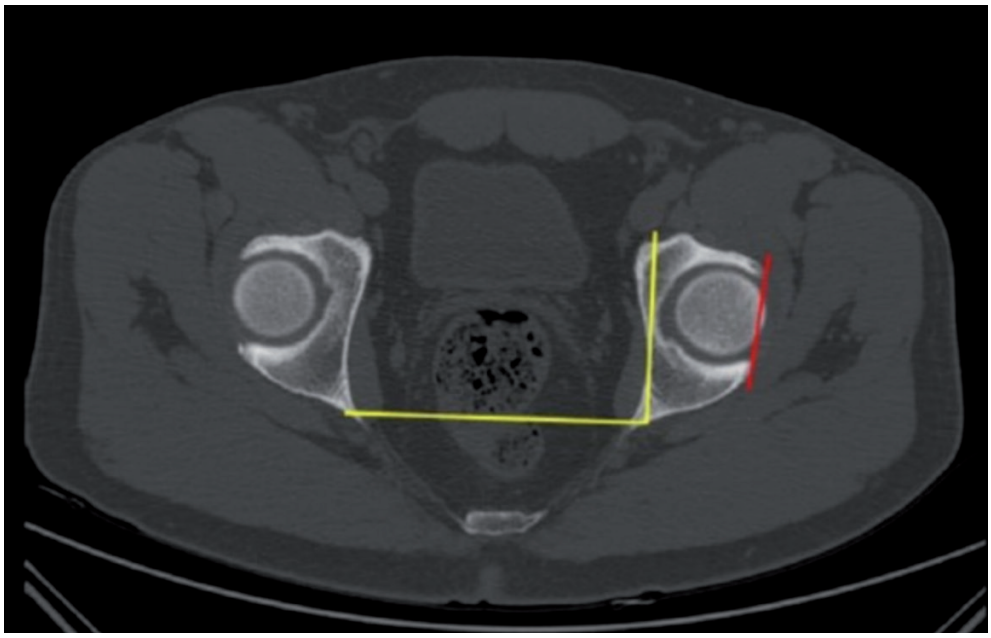

Figure 5: *Anteversion of the acetabulum is measured on a CT-scan in the axial plane (reprint with permission [20])*

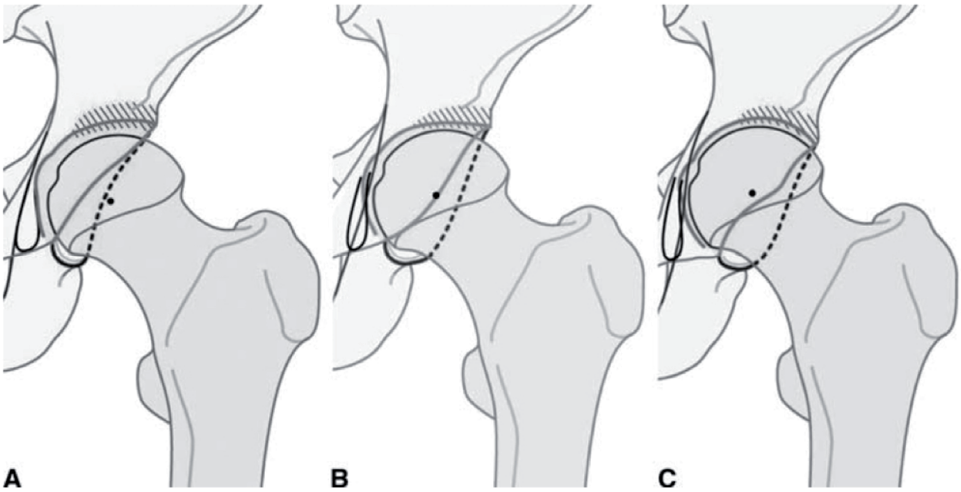

Figure 6: *In the normal hip, the acetabulum provides adequate coverage of the femoral head; B. In coxa profunda, the head is in a more medial position and the acetabular fossa (teardrop) is on or below the ilio-ischial line; C. In protrusio acetabuli, the femoral head is medial to the ilio-ischial line, acetabular roof obliquity is negative, and the centre of the femoral head is medial to the anterior and posterior acetabular wall (reprint with permission [21])*

Other reasons for pincer impingement caused by acetabular overcoverage are coxa profunda or protrusion acetabuli. In coxa profunda the femoral head is more medial and the medial acetabular wall is medial to the ilio-ischial line (figure 6). In protrusion acetabuli both the medial acetabular wall and the femoral head are medial to the ilio-ischial line (figure 6). In both situations there is a deep socket and relative acetabular overcoverage of the femoral head, creating an anatomical base for developing pincer impingement.

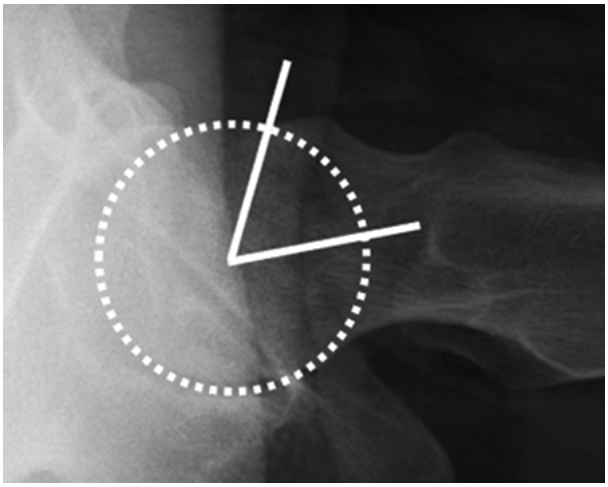

Figure 7: *measuring the alpha angle on a Lauenstein view in a patient with a cam deformity (reprint with permission [22])*

Diagnostic imaging of the impinging hip includes standard AP pelvic radiographs, combined with a lateral femoral neck view to identify possible cam or pincer morphology. Sometimes it is necessary to better visualize the shape of the proximal femur and extra views are needed, such as the Lauenstein view, Dunn view or cross table lateral view [23].

Many radiographic measurements to detect cam or pincer impingement have been described; the increased α-angle in patients with a cam deformity (figure 7), the increased lateral-centre edge angle (LCEA) (figure 8) and/or a positive crossover sign (figure 9) in patients with pincer impingement. These radiological signs might contribute to diagnosing FAIS but it is important to realize that in the asymptomatic population there is also a large portion of people with an increased α-angle, increased LCEA or a positive crossover sign [24].

To diagnose a patient with FAIS, a combination of symptoms, clinical signs and radiological measurements/deformities is mandatory [12].

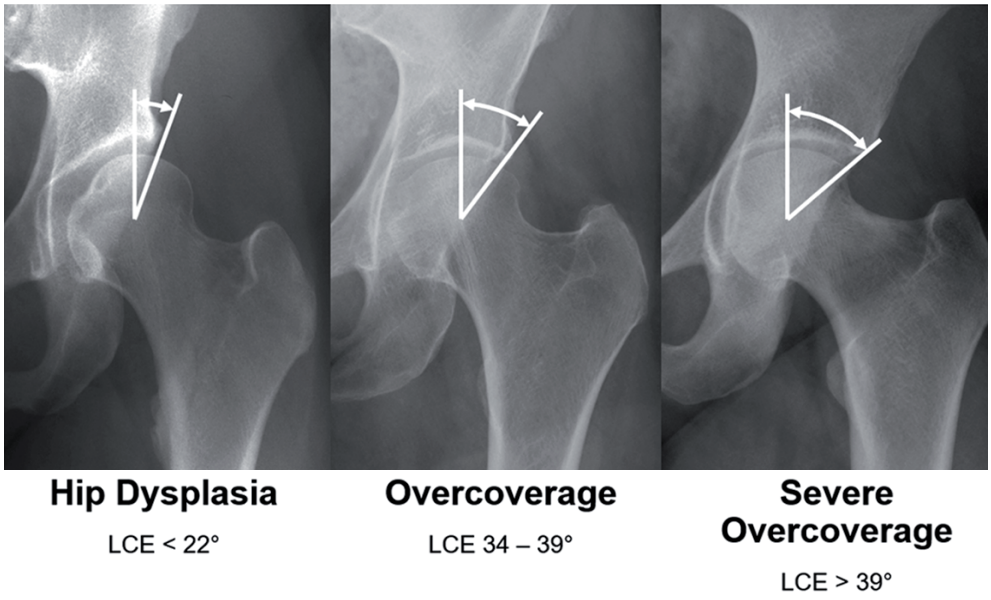

Figure 8: *Measuring the lateral centre edge angle (LCEA). A decreased angle indicates a hip dysplasia and an increased LCEA might indicate acetabular overcoverage seen in patients with pincer impingement (reprint with permission [22])*

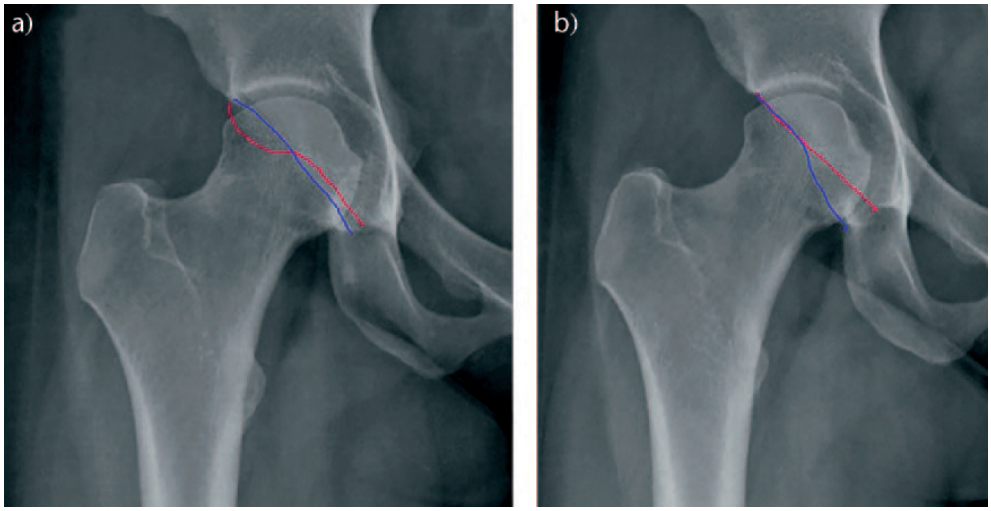

Figure 9: a) Pincer-type impingement before hip arthroscopy. The red line shows the anterior wall, the blue line the posterior wall. A cross-over sign is present. Also note the visible ischial spine sign. b) Same patient after arthroscopic decompression. *(reprint with permission [25])*

TREATMENT OF FAIS

After diagnosing a patient with FAIS several treatment options are available including conservative care, physiotherapy or surgery. Conservative care can include oral analgesia such as nonsteroidal anti-inflammatory drugs (NSAIDs), corticosteroid injection in the hip joint or modification of activities and lifestyle [26]. A physiotherapy program aims to improve hip stability, hip muscle strength and movement patterns. If non-operative treatment fails there is the possibility of surgery, mainly in the form of hip arthroscopy. During hip arthroscopy it is possible to reshape a cam deformity and/or trim the acetabular rim in patients with a pincer deformity. During hip arthroscopy it is also possible to determine the quality of the labrum and perform a labral repair or labral resection if the labrum is not reparable or of poor quality.

As hip arthroscopy is a relatively new technique, it had to prove its therapeutic value in the beginning. An important paper was published in 2018 by Griffin et al., who reported the results of the UK Fashion study in the Lancet [27]. In this randomized controlled trial, they compared hip arthroscopy versus a structured physical therapy program in patients with FAIS. After 12 months of follow-up, the group of patients treated with hip arthroscopy showed superior clinical results compared to the physiotherapy group [27]. Hip arthroscopy has finally proven to earn its place in orthopedics.

BORDERLINE DYSPLASIA OF THE HIP

Another entity of hip pathology is (borderline) dysplasia of the hip. Hip stability mainly arises from the osseous structures (being the acetabulum and femoral head), capsuloligamentous stabilizers are the acetabular labrum and capsular ligaments (mainly the iliofemoral ligament) [5]. Hip dysplasia affects the joint congruency and might influence the stability of the hip. In patients with hip dysplasia the acetabulum is shallow and anteverted, usually accompanied with a compensatory enlarged labrum, the femur is usually in valgus with high anteversion [28]. In patients with hip dysplasia the contact area between acetabulum and femur is reduced and this leads to excessive loading on articular cartilage and acetabular labrum [29]. There are several studies that showed an association between hip dysplasia and labral tears, especially in the anterosuperior part of the labrum [30,31].

Especially in patients with borderline hip dysplasia the labrum and hip capsule plays an important role, in these patients the labrum is hypertrophied to compensate for the acetabular undercoverage of the hip [30,32]. The hip joint capsule acts as a stabilizer and restricts excessive femoral head translation and rotational movement [33]. The most important part of the hip capsule is the iliofemoral ligament (part of the anterior hip capsule) as shown by a cadaveric study of Johannsen et al [33]. Excessive hip rotation

and femoral head translation can lead to capsular instability and increased loading on the labrum and articular cartilage, eventually leading to labral tears or cartilage damage.

Dysplasia of the hip is usually measured with the Lateral Centre Edge Angle (LCEA) of Wiberg and gives an indication of acetabular depth measured on an AP pelvic X-ray (figure 8) [34]. A normal LCEA is between 22 and 39 degrees whereas an LCEA angle of < 20 degrees indicates dysplasia of the hip. An LCEA angle between 20 and 25 degrees indicates borderline dysplasia. Surgical treatment options for patients with significant hip dysplasia (without osteoarthritis) is realignment surgery, for example a peri-acetabular osteotomy combined with a femoral osteotomy.

In the group of patients with borderline dysplasia of the hip there is a role for hip arthroscopy to address intra-articular pathology such as labral tears, cartilage damage and capsular laxity. Domb et al. reported the results of labral repair and capsular plication in a cohort of patients with borderline hip dysplasia. They showed after 5 years of follow-up significant improvement measured on the modified Harris Hip Score, Hip-Outcome-Score (sports) and Non-Arthritic Hip Score [35]. Labral repair and capsular management might be essential in patients with borderline dysplasia to prevent early development of cartilage damage, poor hip function and conversion to total hip arthroplasty.

HIP ARTHROSCOPY

HISTORY OF HIP ARTHROSCOPY

Arthroscopy of the hip was first described in an article by Michael Burman. In 1931 he published on arthroscopy of cadaveric hip joints [36]. He was only able to visualize a part of the femoral head and the intracapsular part of the femoral neck, and he was not able to see the acetabular fossa or the ligamentum teres.

During the first decades after 1931 not much happened in the field of hip arthroscopy until 1987. In that year James Glick published an article on how to insert an arthroscope through the lateral approach with the use of distraction of the ipsilateral hip [37]. The use of distraction was a significant development, and with distraction, it was now possible to enable views of the central compartment of the hip. During the years to follow there were a couple of pioneers that started to explore and experiment with the therapeutic options of hip arthroscopy [38]. Richard Villar was the one that published the first textbook on hip arthroscopy in 1992. Several years later in 2008 the same Richard Villar became the first president of the International Society for Hip Arthroscopy (ISHA). Currently, hip arthroscopy is a widespread and well-established procedure, which is also seen in the increasing numbers of papers published on the matter every year [25].

INDICATIONS AND PATIENT SELECTION IN HIP ARTHROSCOPY

In recent years, the technique of hip arthroscopy has improved, and it is now possible to treat a larger number of patients with different types of hip pathology.

In the central compartment labral tears can be addressed, loose bodies can be removed, and chondral delamination lesions can be stabilized [39]. For cartilage repair, several treatment options are possible, although microfracture remains the standard of care, there are several possible adjuncts to microfracture alone [40–42]. Recent studies have shown that the addition of a soluble substance such as chondrofiller or BST-Cargel results in increased clinical outcomes after surgery [40,41]. Another recent study showed that the addition of bone marrow aspirate concentration after labral repair improves clinical outcome for patients with moderate cartilage damage [42]. These studies suggest that orthobiologics might play a role in the management and treatment of cartilage defects during hip arthroscopy.

Additionally, possible injuries of the ligamentum teres can be managed in the central compartment. In patients with a septic arthritis of the hip, arthroscopy of the hip might be a valid alternative to the more rigorous open arthrotomy that possibly leads to more comorbidity.

In the peripheral compartment, the head-neck junction in patients with a cam deformity can be reshaped until the femoral head moves smoothly again in the acetabular socket. In patients with a pincer deformity, rim trimming and correcting acetabular overcoverage are possible. In the peripheral compartment, synovial biopsies can be performed, and synovial disorders can be treated with the use hip arthroscopy. Other possible indications in the peripheral compartment include capsular disorders and psoas tendon injury/pathology.

Several lesser-known indications for hip arthroscopy include greater trochanteric pain syndrome, decompression of greater trochanteric sciatic nerve impingement, snapping hip disorder, anterior inferior iliac spine impingement or ischiofemoral impingement [39,43,44].

CONTRA-INDICATIONS

Osteoarthritis of the hip joint is a known predictor of early failure following hip arthroscopy [45]. Moreover, in a fully degenerative hip joint, the reduced working space makes surgical maneuvering more challenging. For these reasons, osteoarthritis is clearly considered a contraindication for hip arthroscopy.

But what to do in a young patient with grade 1-2 osteoarthritis? In these patients hip arthroscopy can manage the cam or pincer deformity and therefore delay the development to full blown osteoarthritis. Domb et al proposed a useful algorithm for patients with osteoarthritis in their paper in 2015 (figure 10) [46]. However, in patients with end stage osteoarthritis there is no discussion and there is no role for hip arthroscopy.

Other contraindications for hip arthroscopy are already present neurological disorders related to the pudendal or sciatic nerve because traction during hip arthroscopy might worsen the neurological injury [47].

Additionally, structural anatomical deformities such as developmental dysplasia of the hip (DDH), severe acetabular retroversion or severe protrusio acetabuli are contraindications for arthroscopy and require a different approach. For DDH first choice of treatment is a peri-acetabular osteotomy. In severe acetabular retroversion excessive correction and rim trimming might induce instability and should therefore be avoided. Protrusio acetabuli is treated with surgical dislocation of the femoral head, followed by acetabular rim trimming and labral re-fixation when appropriate.

There are also some relative contraindications for hip arthroscopy. In obese patients, it is conceivable that access to the hip joint is more difficult and sometimes even impossible. A recent study showed that in morbidly obese patients hip arthroscopy does not lead to improved functional results after surgery [48]. Age is considered a relative contraindication, as studies indicate that advancing age correlates with a higher occurrence of degenerative changes in the hip. This increased likelihood further leads to a higher rate of progression towards osteoarthritis, ultimately culminating in the need for total hip arthroplasty. [49].

SURGICAL TECHNIQUE

Hip arthroscopy is performed with the patient on a traction table, either in the supine or lateral position, according to the surgeon's preference [50]. It is important that sufficient traction is applied to the hip; with the use of fluoroscopy, it is now possible to make an entrance to the hip joint with a spinal needle and that the intra-articular vacuum is released [51]. Usually, the first portal is the anterolateral portal just 1 cm anterior to the superior margin of the greater trochanter [52]. The second portal is the anterior or the mid-anterior portal (figure 11). It is possible to make additional portals according to the surgeon's preference or experience. A capsulotomy is performed between portals to create sufficient workspace inside the joint (figure 12) [51,53].

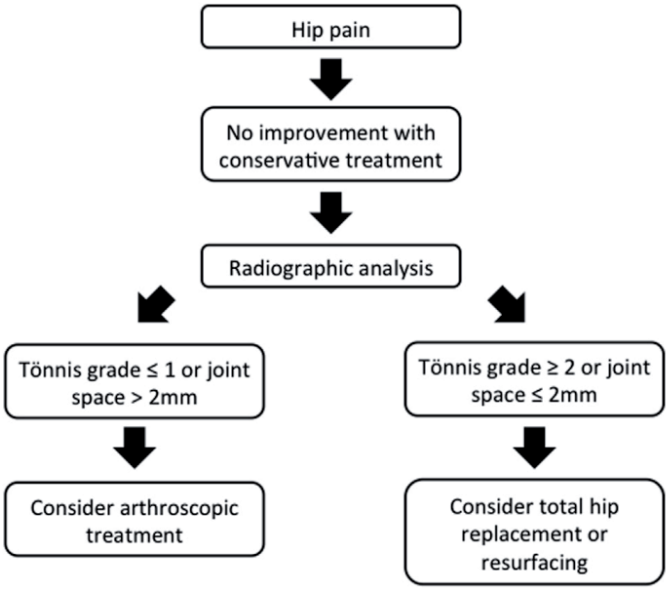

Figure 10: *An algorithm to decide when to consider arthroscopic treatment in patients with osteoarthritis of the hip [46]*

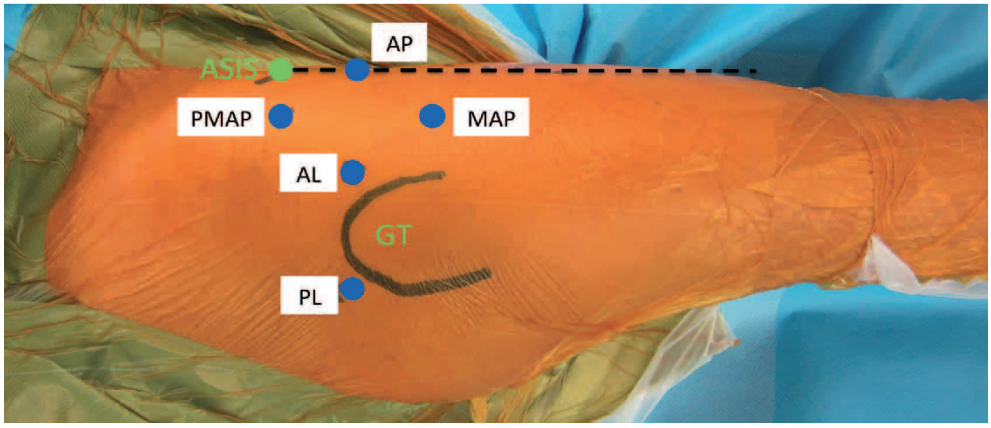

Figure 11: *Positioning of the patient and possible portals in hip arthroscopy. GT= Greater trochanter, ASIS= Anterior inferior iliac spine, PL= Posterolateral, AL= Anterolateral, MAP= Mid-Anterior portal, PMAP= Proximal mid-anterior portal, AP= Anterior portal (reprint with permission [54])*

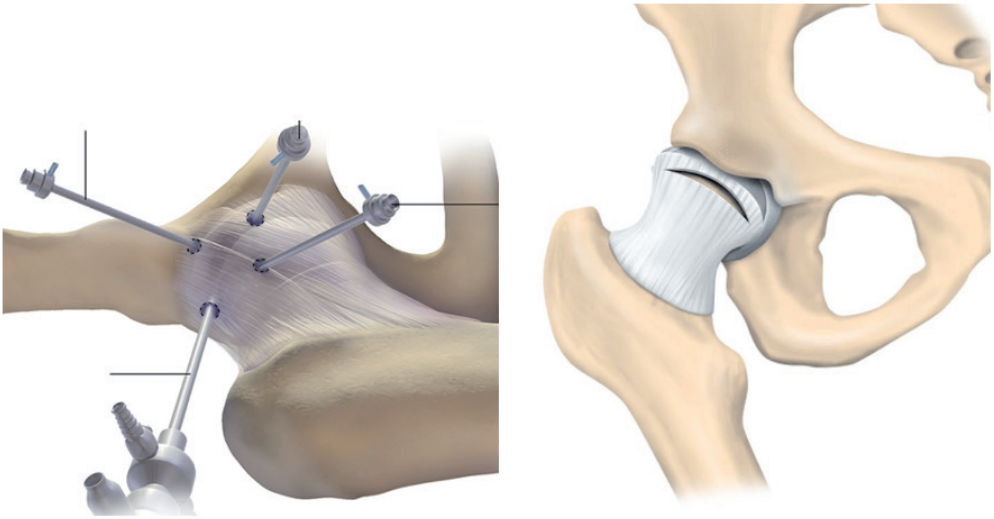

Figure 12: *Portal entrance points through the hip capsule. The right hip shows an interportal capsulotomy is made between portals to create workspace in the joint (reprint with permission [53])*

COMPLICATIONS IN HIP ARTHROSCOPY

Several systematic reviews have evaluated and determined the complication rate after hip arthroscopy [55–57]. The reported complication rate in these reviews is more or less comparable and ranges between 0,41% and 0,58% for major complications and 4,1% and 7,9% for minor complications. Major complications during hip arthroscopy are rare, and the most reported major complication is abdominal fluid extravasation (5% of all complications reported) [57]. Minor complications are more common, and the most reported minor complications are iatrogenic damage to the cartilage or labrum, the formation of heterotopic ossifications and temporary nerve injury [57]. Temporary neuropraxia of the pudendal nerve and the lateral femoral cutaneous nerve were the most reported neurovascular complications [56]. The reoperation rate after hip arthroscopy was described by Gupta et al. and Harris et al. as 4% and 6,3%, respectively [56,57]. The most common reason for reintervention was the placement of total hip arthroplasty (46%) [56].

FUNCTIONAL OUTCOME AFTER HIP ARTHROSCOPY

It is important to realize that there are numerous indications for hip arthroscopy and that the indication itself is a factor that influences the outcome after surgery. An older patient with a degenerative labrum who already presents with osteoarthritis is different than the young athletic football player with a cam deformity. Registry studies show that the most frequently performed procedures during hip arthroscopy are femoroplasty,

pincer resection or labral repair and that the vast majority of hip arthroscopy patients are patients with FAIS [58].

The most important paper regarding outcome after hip arthroscopy in patients with FAIS is the randomized controlled trial published by Griffin et al in the Lancet in 2018 [27]. In this trial, 348 patients were either allocated for hip arthroscopy or a personalized physical therapy program. The results showed that hip arthroscopy for FAIS led to significantly higher functional outcomes than personalized physical therapy alone, and also that this difference between groups was clinically relevant [27]. In a more recent randomized trial by Martin et al., they reported on hip arthroscopy versus physical therapy in a group of patients older than 40 years and with a labral tear. The patients treated with hip arthroscopy and physical therapy showed superior clinical results compared to physical therapy alone [59].

An interesting paper by B. Domb et al described the evolution of hip arthroscopy between 2008 and 2020 [60]. In this article patient selection, surgical technique and outcome of the procedure in 2020 are compared to the results of patients operated on in 2008 by the same surgeon. There are several differences between "now and then"; for example, in current practice, the labrum is more often repaired instead of simply debrided and less often are patients with already signs of hip osteoarthritis selected for surgery [60]. Other surgical factors also change over time; a recent study shows the emergence of high-volume hip arthroscopy surgeons in previous years [61]. Higher volume and familiarization with the procedure decrease surgical operating time, and the traction time is shorter; these improvements possibly lead to fewer complications [61]. The paper of Domb et al. gives a good insight that arthroscopy of the hip is still evolving and is in its "younger years". It seems that patient selection and improving surgical techniques are key to optimising outcomes after hip arthroscopy.

Over the past few decades, hip arthroscopy has significantly evolved, providing a greater understanding of the procedure, surgical techniques, and potential benefits. However, there remain some areas needing further exploration. Specifically, improving patient selection for hip arthroscopy is still an area with room for enhancement. Consequently, the first part of this thesis focuses on patient selection for hip arthroscopy.

In **Chapter 2** the results of a systematic review regarding hip arthroscopy in obese patients are described. Although this paper was already published several years ago in 2015 results are still relevant as it seems that recent literature shows comparable results [48].

As highlighted in the introduction section, not all patients are ideal candidates for hip arthroscopy. The patient with a degenerative labrum or with signs of osteoarthritis might

not benefit at all from an operation. Conversely, there are also patients with lesser-known types of hip impingement which might be very suitable for hip arthroscopy. **Chapter 3** describes three such rare types of impingement. Despite the rarity, it is important for hip surgeons to recognize these types and be aware of potential treatment options.

To determine a patient's suitability for hip arthroscopy, having a correct orthopedic diagnosis is crucial. However, even with a correct diagnosis, it is equally important to consider if the patient is suitable for surgery or not. Certain patient factors can lead to poorer outcomes after hip arthroscopy and are essential for managing patient expectations. To ensure clear patient selection, the influence of pain catastrophizing and the role of preoperative pain scores on outcomes after hip arthroscopy is investigated in **Chapter 4**.

Optimising patient selection reduces unnecessary operations, prevents unnecessary complications and enhances surgical outcomes. The second goal of this thesis focuses on additional factors that can potentially improve outcomes after hip arthroscopy.

Multiple factors were determined with the goal of improving outcomes after hip arthroscopy. One such factor is optimising peri-operative pain management. In **Chapter 5**, a review is described discussing various options for managing pain during the peri-operative period.

Another factor that might have potential in optimising outcome is hip capsular management, this has been a prominent topic in hip arthroscopy literature in recent years. The best treatment strategy remains unclear. To address this, we conducted a randomized controlled trial comparing patients who underwent capsular repair with those who had an unrepaired capsulotomy at the end of hip arthroscopy. The results of this randomized controlled trial are described in **Chapter 6.**

Following the completion of the randomized controlled trial, a subsequent study was structured to assess the hip capsule's integrity through MRI images. **Chapter 7** shows the findings of this follow-up research and offers potential insights into enhancing outcomes after hip arthroscopy.

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PART 1

1

Part 1

PATIENT SELECTION

CHAPTER 2

2

Chapter 2

HIP ARTHROSCOPY IN OBESE, A SUCCESSFUL COMBINATION?

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ABSTRACT

Discussion persists about the outcome and results of hip arthroscopy in obese patients. Hip arthroscopy gained popularity over time. A current discussion is if obese patients can reach similar results after surgery compared with non-obese. To our knowledge, this is the first systematic review of literature about hip arthroscopy and obesity. We searched the Pubmed/Medline databases for literature and included three studies that compared the outcome of hip arthroscopy between different BMI groups. We extracted and pooled the data. For continues data a weighted mean difference was calculated, for dichotomous variables a weighted odds ratio (OR) was calculated using Review Software Manager. Heterogeneity of the included studies was calculated using I2 statistics. Data were extracted from two studies.

In the Obese group, there was significant more conversion to total hip replacement or resurfacing hip replacement (OR.2.21, 95% CI 1.07–4.56) and more re-arthroscopy (OR.4.68, 95% CI 1.41–15.45). Any reoperation occurred more often in the obese group (OR.2.87, 95% CI 1.53–5.38). In the Non-Arthritic Hip Score obese scored lower than the non-Obese group [10.9 (14,6 to 7.1)].

For the modified Harris Hip Score the score is 6,6, according to the MCID this difference is clinically relevant. For both scores obese show lower outcomes but similar improvement after hip arthroscopy. Regarding a higher chance of needing a re-operation and lower subjective outcome scores obesity appears to have a negative influence on the outcome of hip arthroscopy.

INTRODUCTION

The clinical applications of hip arthroscopy evolved mainly last decade. An important indication for hip arthroscopy nowadays is the management of symptomatic FAI and labral tears. Surgical treatment of FAI aims to improve symptoms, increase function and prevent the possible progression to end stage hip osteoarthritis and total hip arthroplasty.

A possible risk factor to develop osteoarthritis of the hip is obesity. A review performed by Jiang et al. [1] shows that an increased body mass index (BMI) contributes to a positive effect on susceptibility of hip osteoarthritis.

Obesity is a worldwide health problem with more than 1.9 billion adults (18 years and older) being overweight and 600 million of these people being obese [2]. Overweight is classified as a BMI>25 kg/m2 and obesity as a BMI>30 kg/m2. An MRI study performed by Teichtahl et al. [3] showed that obesity is associated with deformities of the acetabulum, especially increasing acetabular depth. This is associated with reduced femoral head cartilage and might be an explanation of the increased risk of hip osteoarthritis in obese, or predisposing impingement. The development of osteoarthritis in obese patients may depend more on their weight, rather than an FAI problem.

Clohisy et al. [4] recently studied the epidemiology of surgical interventions for symptomatic FAI, and showed that almost 42% of patients operated for FAI are overweight or obese. A program existing of exercises and weight loss has been shown to be a successful treatment for patients with hip osteoarthritis and overweight or obesity [5]. It is also debatable whether obese patients can really develop FAI as the range of motion of obese patients for flexion and internal rotation is limited [6].

It has been recognized that there is a correlation between obesity and various joint complaints [7]. A study performed by Rajamaki et al. [8] showed that patients with diabetes have more persistent joint pain after knee or hip surgery. It is known that diabetes is more common in obese than non-obese patients therefore it is understandable that obese patients might suffer persistent joint pain after hip arthroscopy.

The purpose of this study was to systematically review the literature on the outcomes of hip arthroscopy in obese patients compared with non-obese. Our hypothesis was that obese patients profit less of hip arthroscopy, have more complications and have worse subjective patient reported outcome measures.

METHODS

A research protocol was developed as described by Wright et al. [9] and used throughout the study process. This protocol was not registered. A literature search was performed through the Pubmed/Medline databases on the 26 March 2015. The following Mesh terms were used: (obesity OR body weight OR Body Mass Index) AND (hip AND arthroscopy).

Furthermore, the lists of references of retrieved publications were manually checked for additional studies potentially meeting the inclusion criteria but not found by the electronic search. Two investigators independently reviewed the literature to identify relevant articles for full review. From the full text, using the above-mentioned criteria, the reviewers independently selected articles for inclusion in this review. Studies were included if they were comparative trials comparing the outcome of hip arthroscopy between different BMI groups. Review articles, expert opinions, surgical techniques and abstracts from scientific meetings were excluded. Only articles written in English were included. Studies were not blinded regarding author, affiliation or source. This systematic review and meta-analysis were done according to the PRISMA guidelines.

Our primary research question was to determine whether the outcome of hip arthroscopy is influenced by BMI. Our outcomes were complications; patient-reported outcome measures, reoperation rates and conversion rates into arthroplasty.

STATISTICS

One reviewer using a pre-piloted data extraction tool extracted the data from the studies included, and the second reviewer verified them. Then the available data from the selected studies were pooled using the Review Manager software from the Cochrane Collaboration. For outcome variables with a continuous nature, a weighted mean difference was calculated with 95% confidence interval (CI). For the dichotomous variables, a weighted odd ratio (OR) with 95% CI was calculated using Review Manager software.

For the studies where continuous variables were reported with a range, the SD was calculated. The heterogeneity of the studies included was calculated using I2 statistics.

This measurement describes the percentage of variation across studies, which is due to heterogeneity rather than chance [10]. We also assessed heterogeneity by means of a Chi-square analysis, whereby a P value of<0.1 was considered to be suggestive of statistical heterogeneity.

RESULTS

Three studies were identified, of which two are from the same author. Gupta et al. [6, 11] reported in 2015 in two articles on a patient population that is operated on by the same senior author in the same time period, we therefore suspect that both are the same population and included only the larger of the two series. We included the larger cohort analysis with 562 patients in the non-obese group, 94 patients in the class 1 obese group and 24 in the class 2 obese group. In Collins et al.'s [12] study, 39 patients were enrolled, 18 non-obese and 21 in the obese group. In Collins study, there was no significant difference in demographics, in Gupta's study the class 1 obese group was significantly older than the non-obese group.

Both included studies report of an average of 2.5 years follow up (Fig. 1). For analysis purposes we combined the Class 1 and Class 2 obesity groups from the Gupta study into one group defined as obese to allow pooling with the second study of Collins et al. [6, 12].

Conversion to THR (or resurfacing) shows an OR of 2.2 (1.1–4.6) in favour of the non-obese (Fig. 2). Rearthroscopy can be defined as failure of previous arthroscopic surgery, showing a pooled OR of 4.7 (1.4–15.5) in favour of the non-obese group (Fig. 3). Any reoperation on the same hip shows an OR of 2.9 (1.5–5.4) (Fig. 4).

When comparing the complications between the groups, no significant difference was found [OR 1.8 (0.8–3.9)], pooled complications rate are 4% in the non-obese group and 9% in the obese group (Fig. 5).

Subjective outcomes in obese are lower than in the non-obese population. For the modified Harris Hip Score (mHHS) this score is below 80 in the obese population, which is classified in the original HHS publication as a fair outcome [13]. The difference after pooling [-6.6 (-10.2 to -2.9)] is more than the MCID for the HHS, being 4, therefore it can be said that the outcome difference is clinically relevant.

The Non Arthritic Hip Score (NAHS) in which the obese score 10.9 lower than the non-obese (-14.6 to -7.2) (Figs. 6 and 7).

In Gupta's series, the non-obese start at significantly higher patient reported outcomes at baseline. All three groups show similar significant improvement postoperatively. There was no significant difference in change of patient reported outcomes between the nonobese group and either one of the obese groups.

In Collins series, both groups showed a statistically significant improvement from baseline for as well the NAHS as the mHHS. There was no significant difference between baseline and change in the NAHS

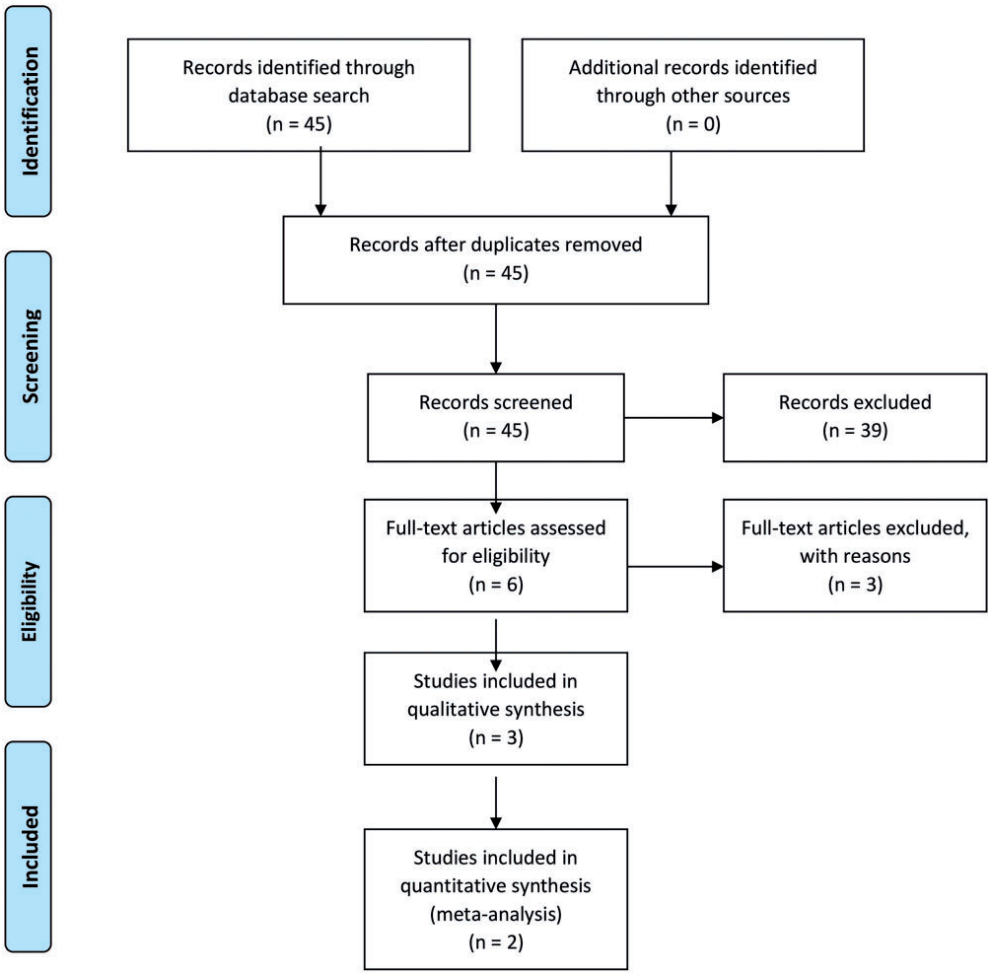

Figure 1: *Prisma flow chart*

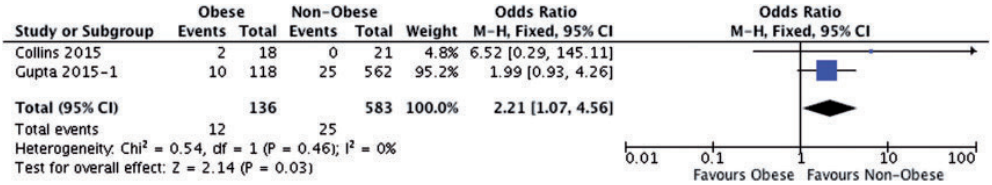

Figure 2: *Conversion to THR or resurfacing hip prosthesis.*

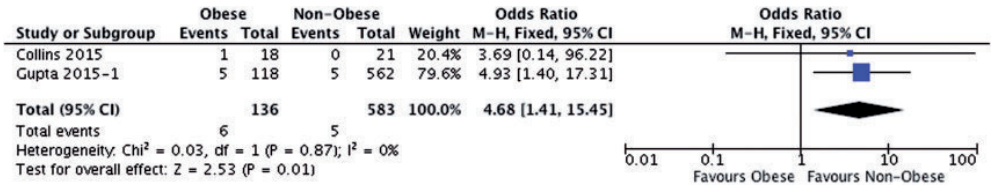

Figure 3: *Re-arthroscopy rate*

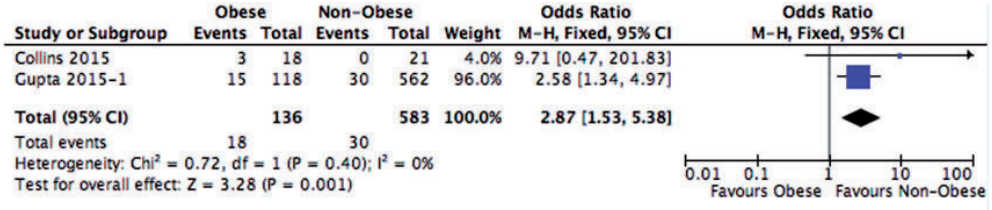

Figure 4: *Conversion to THR or resurfacing hip prosthesis and re-arthroscopy rate combined.*

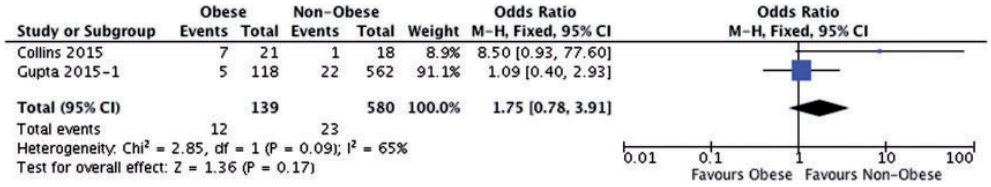

Figure 5: *Complications.*

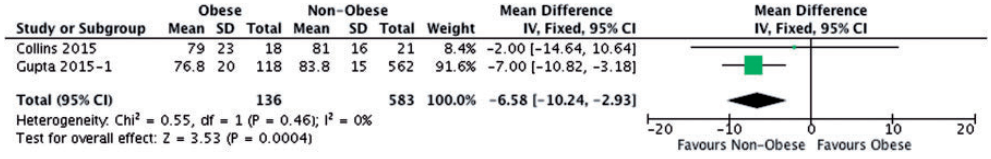

Figure 6: *Harris Hip Score.*

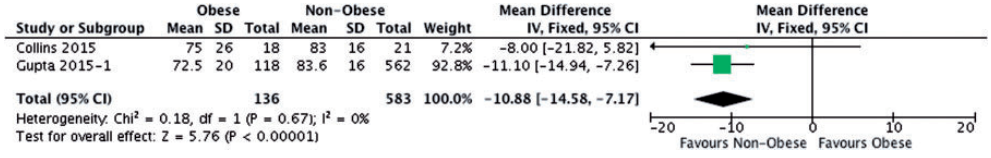

Figure 7: *Non Arthritic Hip Score.*

DISCUSSION

Our systematic review shows that the results of hip arthroscopy in obese might have a poorer outcome. Although obese patients show similar improvement after surgery, subjective outcome scores are lower at follow up and re-arthroscopy rates are 4.7 times higher and conversion to hip replacement 2.2 times higher for obese.

The main concern is that two recent publications by the same group conclude that the outcome of hip arthroscopy in obese is comparable to that in non-obese. However, the included study of Gupta has some flaws. First, reoperation rate is divided in re-arthroscopy, total hip replacement (THR) and resurfacing and all these comparisons do not reach significance. Dividing resurfacing and THR in different groups is in our opinion not correct since both are hip replacement surgery.

The main shortcoming of our review is that only two studies were suitable for inclusion, though both were comparative studies of prospectively followed patients. However, we feel that our review is an important addition to the current knowledge. A quick reader may conclude that there are three studies showing non-inferior results in obese, while the result in obese may indeed be inferior compared to non-obese.

In Gupta's series, there was a higher percentage of patients in the obese Class 1 and Class 2 groups who went for revision arthroscopies. This could be due to the higher percentage of capsular release in these groups (70.2 and 62.5%).

Both included studies used for the meta-analysis are performed in the USA where 68% of the general adult population is obese [14]. There are several other confounding factors associated with different BMI in the USA: socioeconomic class, income or race for example.

Patients with a high BMI more often origin from a lower socioeconomic class [14]. These patients have fewer financial means and if primary surgery fails or is inadequate, they might earlier opt for a definite solution; THR. Diabetes is more common in obese patients than nonobese. Rajamaki et al. [8] showed that diabetic patients suffer more postoperative pain after knee and hip surgery. This can be another reason that obese patients might earlier opt for hip replacement surgery. In retrospective studies comparing obese and non-obese, the presence of selection bias is indeed not unlikely. Besides that, the studies do not mention whether the patients were obese their whole life, or even if they were already obese when the complaints started, just the BMI at time of surgery is stated. By not knowing BMI change over time it is more difficult to judge several details of this group.

There is paucity in literature regarding obesity and arthroscopy of the hip but there is comparative literature from arthroscopic knee surgery. Erdil et al. [15] evaluated the results of more than 1000 patients who underwent knee arthroscopy for partial meniscectomy. They compared the effect of BMI on functional outcome and divided all patients in one of three groups; (1) normal weight (BMI<26 kg/m2), (2) overweight (BMI of >26–29.9 kg/m2) and (3) obese (BMI>30 kg/m2). Compared with the normal weight group, both the overweight as the obese group showed significant worse short-term outcomes using the International Knee Documentation Committee, the Lysholm Knee Scale and Oxford Scoring System scores.

Harrison et al. [16] compared the results of knee arthroscopy in overweight women versus normal weight women 4–11 years after surgery. In all domains of the SF-36 questionnaire, obese women showed significant lower outcome scores and were less satisfied.

It is quite understandable that performing hip arthroscopy on obese patients can be more challenging regarding patient positioning, portal placement and traction times. All these factors result in longer operative times and therefore can lead to more complications. In this study, there were not significant more complications in the obese population, however with an OR of 1.75 the non-significance may be caused by lack of power.

A study of Paans et al. [5] showed that with an 8-month program of physical therapy and weight loss, patients with degenerative hip complaints had an improvement of 33% on the WOMAC scale. In the included studies an improvement was reached in 2.5 years of 28% in the study of Gupta et al. and 43% in the study of Collins. In both studies, the duration of physical therapy and the weight change over time is not included in the analysis. It is not uncommon for hip arthroscopy patients to start vigorous rehabilitation programs after surgery in which weight reduction could be part of the goal. This might create a bias if not included in the final analysis.

A lot can be said over the cause of hip pain and the problems that can be solved with hip arthroscopy, and that clear indications might give good results even in the obese. The problem in analyzing the data is that in both studies every hip arthroscopy, for every indication, is combined. In the study of Collins et al., the pathology remains intraarticular, whereas in the study of Gupta et al.'s even extraarticular procedures like IT band release, sciatic nerve decompression and piriformis release are included. This heterogeneous group makes it impossible to state something about specific indications in combination with obesity and the possible outcome of hip arthroscopy.

CONCLUSION

Hip arthroscopy in obese show similar improved results after surgery, but with lower overall outcome scores and more re-operations one can question if hip arthroscopy is the right option in obese patients. Since obesity itself can possibly be the causative factor, we advise caution with surgical interventions and focus more on weight loss programs with physical therapy prior to surgery.

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CHAPTER 3

Chapter 3

IMPINGEMENT AROUND THE HIP: BEYOND CAM AND PINCER

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ABSTRACT

In this review, we bring to the attention of the reader three relatively unknown types of hip impingement. We explain the concept of low anterior inferior iliac spine (AIIS) impingement, also known as sub-spine impingement, ischio-femoral impingement (IFI) and pelvi-trochanteric impingement. For each type of impingement, we performed a search of relevant literature. We searched the PubMed, Medline (Ovid) and Embase databases from 1960 to March 2016. For each different type of impingement, a different search strategy was conducted. In total, 19 studies were included and described. No data analysis was performed since there was not much comparable data between studies. An overview of symptoms, clinical tests and possible surgical treatment options for the three different types of extra-articular impingement is provided. Several disorders around the hip can cause similar complaints.

Therefore, we plead for a standardized classification. In young and athletic patients, in particular, there is much to gain if hip impingement is diagnosed early.

INTRODUCTION

The concept of impingement is not a new one and can be found in orthopedic textbooks predating 1900. Interest in hip impingement increased considerably after hip arthroscopy was accepted as a feasible treatment possibility. Burman was the first to look inside the hip and performed arthroscopy of the hip in cadavers [1]. Since he used no distraction, it was not very successful and clinical interest in arthroscopy declined. During the last several decades, the number of publications on hip arthroscopy and hip impingement has grown steadily. Now cam (Fig. 1) and pincer impingement are recognized as entities that are treatable and are seen and recognized by many orthopedic surgeons and not just hip specialists.

It is now time to draw attention to the more unusual types of impingement, since these are often not recognized in general orthopedic practice. This review discusses three types of lesser-known causes of hip impingement and the current literature.

CLASSICAL IMPINGEMENT: CAM AND PINCER

The definition of femoro-acetabular impingement (FAI) using the distinction between cam and pincer was made by Ganz et al. In 1991, they described a group of six patients with FAI-type complaints after a fracture of the femoral neck [2]. Since then, several articles have been published reviewing FAI (Fig. 2) and the terms 'cam' and 'pincer' have been introduced.

FAI is normally morphologically subdivided into two types, cam and pincer, although a number of patients show signs of both types simultaneously, also known as the 'combined' or 'mixed' types.

The cam type is characterized by femoral head/neck junction malformations that result in shearing forces on the labrum and the articular cartilage (Fig. 1). The impingement can be caused by a congenital hip problem but mostly no pre-existing cause is found [3]. Cam-type FAI is most often found in young, athletic men [4].

Pincer impingement is more common in middle-aged athletic women [4]. In these patients, the acetabulum covers too much of the femur head (Fig. 3). General over-coverage of the femoral head is seen in a protrusion acetabuli or as part of an overgrowth of the anterior wall. Another cause of pincer impingement is seen in cases of acetabular retroversion (normal acetabular anteversion is 15° to 20°) [5]. Acetabular retroversion causes over-coverage of the anterior wall, seen as a 'cross-over' sign on the radiograph (Fig. 3) [6,7].

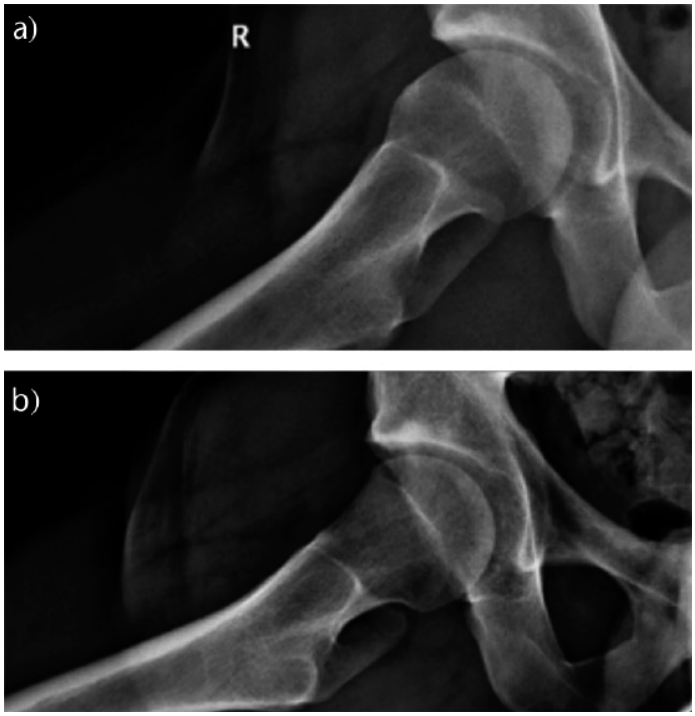

Figure 1: *a) Cam-type impingement before hip arthroscopy; b) same patient after arthroscopic cam resection.*

The combined or mixed type shows morphologies of both cam and pincer simultaneously and is quite common in most studies [8,9]. Cam and pincer impingement are well-known indications for hip arthroscopy and many publications can be found related to this topic. However, we must bear in mind and realize that these are just the intra-articular causes for hip impingement.

Arthroscopic treatment of FAI in the literature is shown to be effective in terms of short-term pain relief and functional outcome [3,10-12]. Arthroscopic osteoplasty is equally effective as open surgical dislocation for anterior and antero-superior cam and focal rim impingement lesions, but post-operative recovery is faster compared with the open procedure and early correction of FAI improves hip pain [4,13].

A study by Beck et al in 2004 of 158 patients showed that most patients reported 95% of their pain resolved one year after hip arthroscopy [14]. Primary arthroscopic decompression is now accepted as a successful procedure with low rates of major and minor complications.

There is, however, a learning curve for performing hip arthroscopy [9,15]. Hip arthroscopy is successful in the majority of patients, but sometimes revision hip arthroscopy has to be performed. The main reason for revision arthroscopy is incomplete correction and persistence of residual deformity [16,17]. Although there is evidence that surgery can improve symptoms in the short term, there still is no evidence that it slows the development of osteoarthritis (OA).

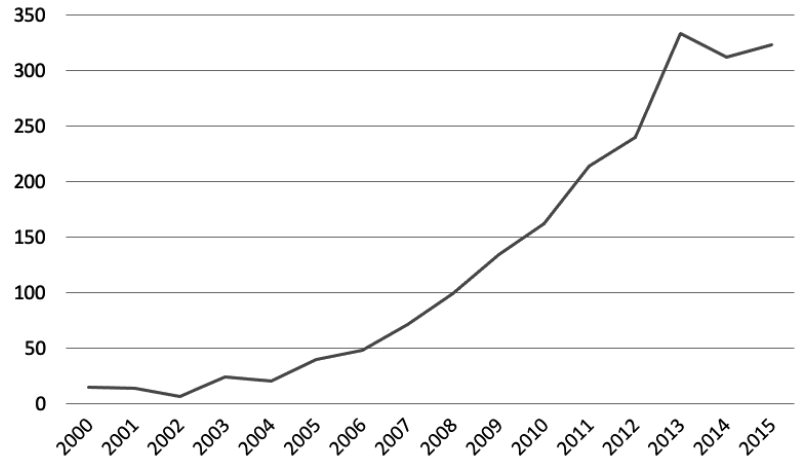

Figure 2: *Number of FAI publications published every year.*

MATERIALS AND METHODS

A research protocol was developed as described by Wright et al and used throughout the study process [18]. This protocol was not registered. A literature search was performed of the PubMed, Medline (Ovid) and Embase databases from 1960 to March 2016. For each different type of impingement, a different search strategy was conducted. For the low anterior inferior iliac spine (AIIS) impingement, the following search terms were used: ((femoracetabular impingement OR impingement OR avulsion) and (subspine OR ssi OR anterior inferior iliac)).

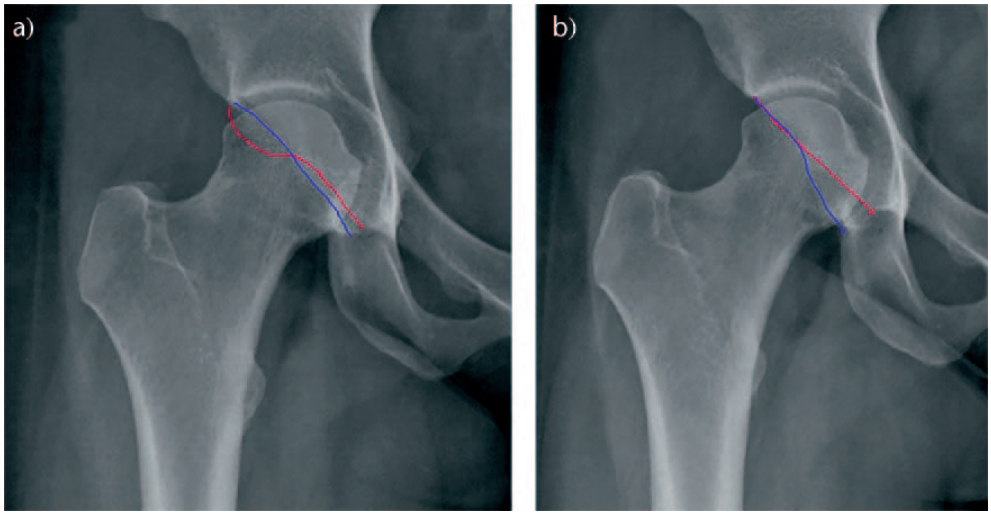

Figure 3: *a) Pincer-type impingement before hip arthroscopy. The red line shows the anterior wall, the blue line the posterior wall. A cross-over sign is present. Also note the visible ischial spine sign. b) Same patient after arthroscopic decompression.*

For ischiofemoral impingement (IFI), the search contained the terms: ((femoracetabular impingement OR impingement OR avulsion) and (ischiofemoral)). For the pelvitrochanteric-type impingement, the search terms were: ((femoracetabular impingement OR impingement

OR avulsion) and (trochanter OR pelvitrochanter OR greater trochanter OR psoas OR iliopsoas OR snapping hip)). Articles were deemed eligible if the study was of patients aged 12 years and older and who had undergone surgical treatment for one of the three types of impingement. Only surgical studies were included. Radiographic analysis studies, reviews, course lectures and cadaveric studies were excluded. Furthermore, only English language studies were included.

Two investigators (NB and DH) independently reviewed the literature to identify relevant articles for full review. From the full text, using the above-mentioned criteria, the reviewers independently selected articles for inclusion in this review. The lists of references of retrieved publications were manually checked for additional studies potentially meeting the inclusion criteria but not found by the electronic search. Disagreements were addressed by discussion between reviewers 1 and 2 and conflicts were resolved. No data analysis was performed since there was not much comparable data between studies.

ANTERIOR INFERIOR ILIAC SPINE IMPINGEMENT

Besides the classical impingement types, there are also some types of extra-articular impingement. The first is AIIS impingement or sub-spine impingement (SSI). In the literature, not much can be found about this type of impingement and it is unknown to many clinicians who are seeing patients with groin pain. Similarly, little literature is available discussing AIIS impingement or SSI, and even less about treatment options (Table 1).

Pan et al first described it as an impingement type in 2008 [19]. In this type of extra-articular impingement, the femoral neck or head/neck junction impinges on the AIIS (Fig. 4); the AIIS can be too large due to hypertrophy, previous avulsion or corrective osteotomies. Symptoms are identical to cam or pincer impingement, being groin pain on flexion and internal rotation, but with local tenderness over the AIIS and incomplete pain relief on intra-articular marcaine injection (as a diagnostic test).

In a CT-scan study by Hetsroni et al, three types of AIIS impingement were defined: in type I, there is a smooth ilium wall without bony prominences between the caudal level of the AIIS and the anterior-superior acetabular rim [20], in type II, there are bony prominences on the ilium wall extending from the caudal area of the AIIS to the acetabular rim, or alternatively the AIIS appears as a 'roof-like' prominence over the hip at the level of the acetabular rim; and in type III, the AIIS extends distally to the antero-superior acetabular rim. In this case, the AIIS interferes with the continuity of the acetabular rim on CT imaging on the anteroposterior (AP) view or 'head-on AIIS view' or both, and it has a downward 'spur appearance'. Types II and III are associated with a decreased range of motion of hip flexion and internal rotation.

AIIS can be addressed surgically via an open or arthroscopic treatment. The open approach results in excellent pain relief and restoration of hip movement, but is only described in case reports [19,21,22]. Later studies describe excellent short-term outcomes for arthroscopic decompression at the level of the anterior rim [9,23,48]. Short-term outcomes of surgical decompression of the AIIS prominence may be favorable for patients with characteristic anterior hip pain worsened with straight leg hip flexion [24].

In the study by Hetsroni et al, all patients had AIIS impingement combined with at least one other abnormal intra-articular finding (cam lesions, labral tears or rim lesions). Particularly in the patients with mixed intra- and extra-articular components that cause AIIS, arthroscopy is preferable compared with an open procedure since the surgeon is able to address all pathologies in a single arthroscopic procedure [23]. As a more aggressive decompression, a small longitudinal split of the rectus tendon is also described, which can

result in the complication of a detachment of the rectus femoris muscle [9]. To conclude, there is evidence that surgical intervention leads to good results regarding pain and hip movement, but the evidence is scarce and mostly based on case reports.

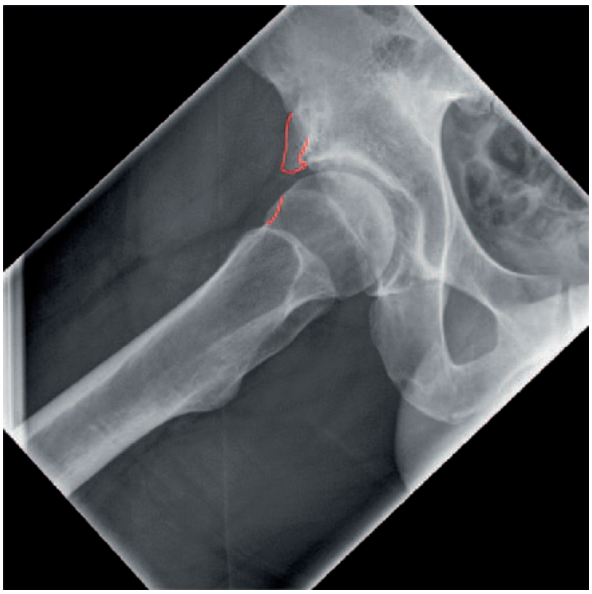

Figure 4: *Low AIIS impingement type III.*

ISCHIOFEMORAL IMPINGEMENT

Another form of extra-articular impingement is IFI, which was first described by Johnson in 1977 as an iatrogenically induced condition following total hip arthroplasty (THA) [43].

Unlike FAI, it is an extra-articular process and there is no direct relationship with acetabular labral tears or chondral damage. This type of impingement occurs when the distance between the lesser trochanter and ischium is too narrow, causing impingement squeezing of the quadratus femoris muscle (Fig. 5) [44]. The normal distance between the lesser trochanter and os ischium is described as being approximately 2 cm [25]. Narrowing of this space can occur in extreme valgus hips or from iatrogenic causes, for instance, by offset loss after THA or extreme valgisation after hip osteotomy.

Patients with IFI report deep gluteal pain as a major complaint [26]. Clinical tests for IFI are the long-stride walking test and IFI test [26]. The long-stride walking test intends to provoke IFI and is considered positive if the patient grabs the affected hip during extension and when pain is relieved during hip abduction (considering the fact that

Table 1: *Articles on surgical treatment for AIIS. HHS: Harris Hip Score. VAS: visual analog scale. ROM: range of motion.*

Author	Sample size	Surgical intervention	Follow up	Outcome Pre-operative	Postoperative	Significance
Larson CM et al. 2011[46]	3 patients	Arthroscopic decompression of AIIS with/ without osteoplasty and labral repair	Mean ± SD 16 ± 3.5 months (range, 12-18 months)	Mean HHS 76 (range 74-79), Mean VAS 6.2 (range 4.85-8.0)	Mean HHS 94 (range 85-100) Mean VAS 1.1 (range 0.0-1.75)	
Hapa O et al. 2013 [9]	163 hips	Arthroscopic decompression of the AIIS with/without CAM resection/rim trim/labral repair with/without other procedures	Mean ± SD 11.1±4.1 months (range 612 months)	Mean modified HHS 63.1 (range 21-90) SF- 12 mean 70.4 (range 34-93) VAS 4.9 (range 0.1-8.6)	mean modified HHS 85.3 (range 37-100) SF- 12 mean 81.3 (range 31-99) VAS 1.9 (range 0-7.8)	HHS (P< .01) SF- 12 (P< .01) VAS (P< .01)
Amar et al. 2013 [48]	1 patient	Arthroscopic rim resection, labral refixation and AIIS and femoral osteoplasty	6 weeks	Not reported	Relief of pain	
Hetsroni I et al. 2012 [23]	10 patients	Arthroscopic decompression of AIIS plus cam resection with/without rim trim plus labral repair or debridement	Mean ± SD, 14.1 ± 7.2 mo (range, 6-26 mo)	Flexion ROM 99 ±7 Modified HHS 64 ± 18	Flexion ROM 117 ± 8 Modified HHS 98 ± 2	Flexion ROM (P<0.001) Modified HHS (P<0.001)

Pan H et al. 2008 [19]	1 patient	Open procedure: detachment of the tensor fascia lata and gluteus medius form iliac crest, detachment of heads of rectus femoris, arthrotomy, AIIS resection	5 weeks	Not reported	Hip flexion 120º, normal range of internal rotation Relief of pain
Rajasekhar et al. 2001[22]	1 patient	Open resection of exuberant callus	30 months	Groin pain, aggravated by flexion of the hip, normal range of movement of both hips	Completely asymptomatic
Irving, 1964. [21]	1 patient	Open resection of exostosis	Not reported	Moderate limitation of rotation and abduction of the hip	Full range of hip movement
Matsuda et al. 2012 [47]	1 patient	Arthroscopic 'spinoplasty' plus CAM resection plus rim trim plus labral refeixation	18 months	Hip flexor strength 4/5, nonarthritic hip score 22, internal rotation 20°	Hip flexor strength 5/5, nonarthritic hip score 98, no restriction hip motion

during hip abduction, the ischiofemoral space widens) or when walking shorter strides [26]. The IFI test is performed with the patient in the contralateral decubitus position and the test is positive when patients complain of the known pain during passive extension and adduction (or neutral) position of the affected hip [26]. During passive extension and abduction, patients are relieved of their buttock pain [26].

Papers reporting IFI that use MRI show that the space between the ischial tuberosity and lesser trochanter is narrowed; in some cases, this can also be caused by femoral rotation (for example, in coxa valga hips). It is important to pay attention to atrophy, inflammation or oedema of the quadratus femoris muscle on the MRI scan since these findings suggest IFI [25,27,45].

Little has been published about treatment options and there is no consensus yet on the optimal treatment for IFI. In 1977, Johnson suggested excision of the lesser trochanter.

Ultrasound-guided steroid injection of the quadratus femoris muscle shows promise as a part of conservative treatment [28,29].

Only a few studies are published which provide information about surgical treatment options for IFI, using an open procedure or arthroscopy (Table 2) [26,30-34]. These studies provide limited, low-quality evidence suggesting surgical intervention to widen the ischiofemoral space by lesser trochanteric excision or ischial tuberosity decompression that may lead to clinical benefit, with minimal risk [24,30,31,33]. Most often, the available research focuses on resection of the lesser trochanter. However, in cases which are iatrogenic, IFI occurs after total hip replacement (THR) because of loss of offset, and a revision of the THR might be a more suitable solution. For extreme coxa valga, restoration of the caput-collum diaphyseal angle (CCD) and offset by performing a classical varus intertrochanteric osteotomy is, in our opinion, a surgical intervention that should not be forgotten.

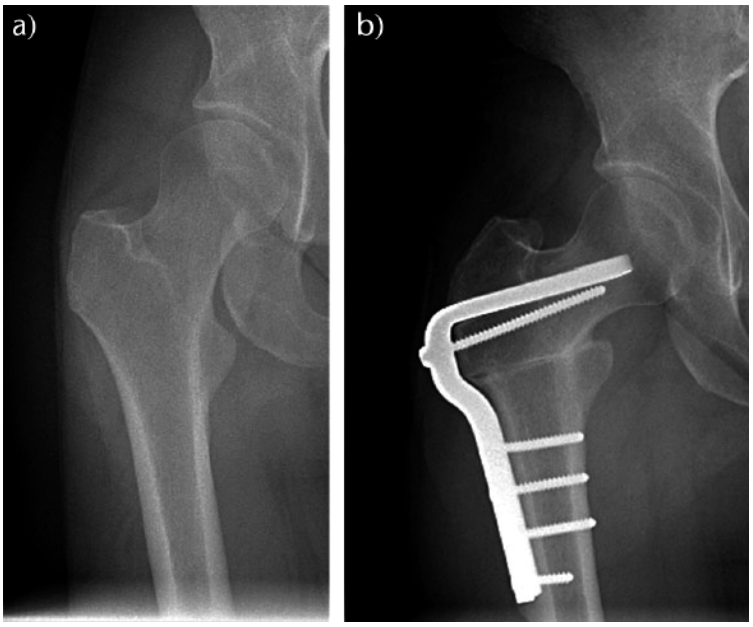

***Figure 5**: a) IFI in a valgus hip; b) a possible solution could be a varus intertrochanteric osteotomy.*

PELVITROCHANTERIC IMPINGEMENT

Besides AIIS and IFI, there is the pelvic-greater trochanter type impingement. This type of impingement is most often seen in patients who suffered from Legg-Calve-Perthes disease, congenital dislocation or a slipped capital femoral epiphysis (SCFE), which can result in a shortened femoral neck, a more prominent greater trochanter in a relative proximal position and a deformed aspherical head (Fig. 6). This causes impingement between the ilium and greater trochanter during abduction of the hip.

Patients complain of pain during walking and symptoms are limping, abductor weakness and decreased range of motion [35]. Standard diagnostic evaluation includes AP pelvic radiograph and lateral radiograph of the proximal femur [35].

The first operative treatment option was described by Jani in 1969 and consisted of a lateralizing osteotomy of the greater trochanter [36].

In 1991, Macnicol and Makris described the typical gear stick sign used to diagnose pelvitrochanteric impingement. During flexion of the hip, full abduction is possible, but when the hip is in full extension, the prominent greater trochanter impinges against the

Table 2: *Articles on surgical treatment for IFI. iHOT: International Hip Outcome Tool. HHS: Harris Hip Score. VAS: visual analog scale.*

Author	Sample size	Surgical intervention	Follow up	Outcome Pre-operative	Postoperative	Significance
Hatem et al. 2014.[26]	5 patients	Endoscopic partial resection of the quadratus muscle, osteoplasty of the lesser trochanter	2.3 years (range 2-2.5)	Mean modified HHS 51.3 (range 34.1-73.7) VAS 6.6 (range 6-7.3)	Mean modified HHS 94.2 (range 78.1-100) VAS 1 (range 0-4)	HHS P=0.003 VAS P=0.001
Safran et al. 2014. [32]	1 patient	Endoscopic iliopsoas bursectomy, total resection of iliopsoas muscle and tendon from the lesser trochanter, excision of the lesser trochanter	2 years	iHOT score 32	iHOT score 85 Pain relief, no involuntary snapping	
Viala et al. 2012. [30]	1 patient	Open resection of exostosis	6 months	Maximal hip flexion at 100°, internal rotation 10–20°, external rotation 40°, and abduction 45°	Hip pain improvement	
Ali et al. 2011. [31]	1 patient	Open resection of lesser trochanter	10 weeks	Audible snapping	No pain No snapping of quadratus femoris No impingement intraoperatively in neutral position of hip in extension	
Ganz et al. 2013. [33]	8 hips	Osteotomy of lesser trochanter, mobilizing and distalizing the fragment and fixation with 2 screws	3,5 years	3 patients hip instability	All hips were healed at 2,5years follow up	
Wilson et al. 2016. [34]	7 patients	All patients iliopsoas tendon release followed by lesser trochanter resection.	Average 20 months	mHHS: average 43 range 20-76	6 wks: average 58 6 mnths: average 86 12mnths: average 91 (range 76-100)	Not mentioned

ilium or posterior rim of the acetabulum [37]. Furthermore, they reported a new satisfying technique in which they distalized the greater trochanter after performing a trochanteric osteotomy. In their review, they report 27 procedures performed over 22 years (Table 3). In all cases, the greater trochanter united without delay. All patients had a positive Trendelenburg sign pre-operatively. Overall, gait improved and most patients reported complete pain relief post-operatively. In some patients with persistent pain, this was mostly due to the development of OA.

Leunig and Ganz reported 14 femoral head reduction osteotomies being performed as a safe and satisfactory technique for Perthes or Perthes-like deformities [38]. Of these 14 patients, eight received an additional pelvic acetabular osteotomy. All osteotomies healed and united without problems and all patients reported satisfying results regarding pain relief.

More recently, a study by Albers et al retrospectively reviewed the results of relative femoral neck lengthening for 41 hips in 40 patients who underwent surgery between 1998 and 2006 [35]. In this group, the proximal femoral deformities were the sequelae of Legg-Calve-Perthes disease in 38 hips (93%), slipped capital femoral epiphysiolysis in two hips (5%) and post-septic arthritis in one hip (2%). Surgery consisted of a greater trochanter osteotomy with reduction of the stable part of the greater trochanter and advancement of the greater trochanter to the proximal femur fixed with multiple screws. Osteochondroplasty of the femoral head-neck area was performed in all hips to reduce offset. Overall functional and radiographic outcomes were satisfactory (Table 3).

In patients with healed Legg-Calve-Perthes hips, there is usually a combination of intra-articular and extra-articular impingement. In the studies by Anderson et al and Shore et al, a combination of femoral head-neck osteochondroplasty and relative femoral neck lengthening by a trochanteric osteotomy was performed [39,40]. In 19 patients with extra-articular impingement, a trochanteric osteotomy with relative femoral neck lengthening was performed. The osteochondroplasty was done to remove the aspherical femoral head to reduce intra-articular impingement. Both studies showed a significant increase in the Harris Hip Score and WOMAC.

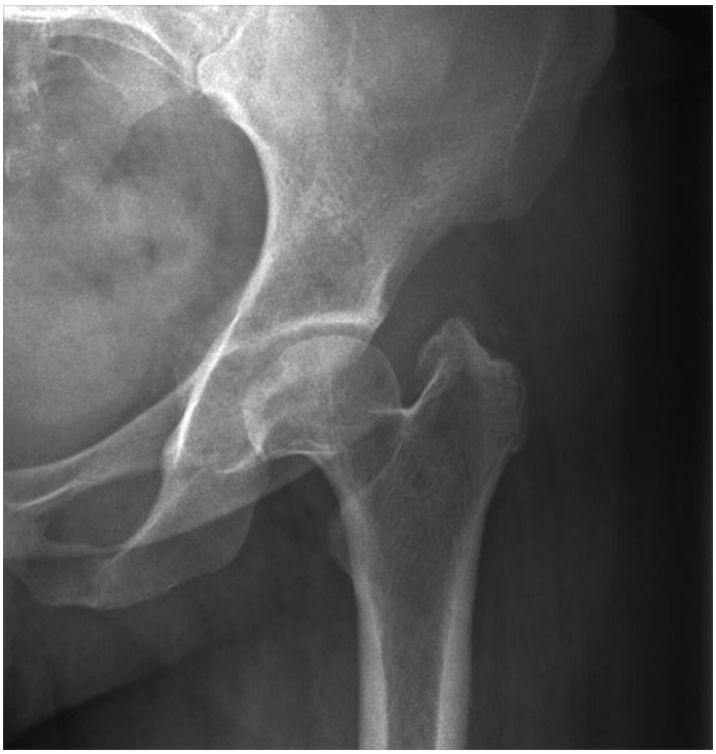

Figure 6: *Left hip of a 45-year-old woman with pelvitrochanteric impingement. Note the high-riding trochanter and short femoral neck.*

Table 3: *Articles on outcome for the surgical treatment of pelvitrochanteric impingement.*

Author	Sample size	Surgical intervention	Follow up	Outcome Pre-operative	Postoperative	Significance
Macnicol et al. 1991. [37]	27 hips (26 patients)	11 derotation osteotomy 15 varus/valgus osteotomy 15 Salter innominate osteotomies, 4 Chiari pelvic osteotomy 1 Wainwright shelf operation	8 years (range 2 -22 yrs)	All patients positive Trendelenburg test	- 81,5% negative Trendelenburg test 2 years after operation - Passive abduction increased by an average of 15° in 13 hips (48%). Remained the same in 10 hips (37%) and decreased in 4 hips (15%). - 74% (20 hips) reported complete pain relief	
Leunig et al. 2011. [38]	14 hips (13 with Perthes or Perthes like deformities)	14 head reduction osteotomies 1 Colonna procedure, 8 pelvic acetabular osteotomies.	Minimum 3 years		Improved motion, without substantial pain	

Albers et al. 2015. [35]	41 hips (40 patients)	Relative femoral neck lengthening with additional osteochondroplasty of head-neck area.	Minimum 5 years (mean 8 years, range 5-13)	Flexion ROM 94° Extension ROM 4° Internal rotation ROM 18° External Rotation ROM 25° Abduction ROM 24° Adduction ROM 18° Anterior impingement test 93% positive Abductor strength: 17% Limping 76% Radiographic: normal trochanteric height (% of hips): 5	Flexion ROM mean 93° Extension ROM 7° Internal rotation ROM 25° External rotation ROM 32° Abduction ROM 37° Adduction ROM 13° Anterior impingement test 49% positive Abductor strength 91% Limping 9% Radiographic: normal trochanteric height (% of hips): 80	Flexion P=0.466 Extension P=0.121 Internal rotation P=0.045 External rotation P=0.013 Abduction P=0.004 Adduction P=0.176 Anterior impingement test P=0.002 Abductor strength P<0.001 Limping P<0.001 Radiographic: normal trochanteric height (% of hips): p<0.001
Anderson et al. 2010. [39]	14 hips (14 patients)	All patients underwent surgical dislocation, osteochondroplasty and trochanteric advancement	Mean 45 months	Harris Hip Score: mean 66 Limping: 11 patients	HHS: mean 87	HHS P<0.0001
Shore et al 2012. [40]	29 hips (29 patients)	All patients: femoral head-neck osteochondroplasty 19 relative femoral neck lengthening 12 intertrochanteric osteotomy 5 labral debridement 1 periacetabular osteotomy	Minimal 1 year, mean: 36 months (range 12-70 months)	WOMAC pain mean 8,4 WOMAC function mean 21,2 WOMAC stiffness mean 3,7	WOMAC pain mean 3,5 WOMAC function 12,5 WOMAC stiffness 2,0	WOMAC pain P<0.0001 WOMAC function P=0.0009 WOMAC stiffness P=0.004

DISCUSSION

In this review, we have given an overview of three extraarticular types of hip impingement that are as yet unknown to the majority of orthopedic surgeons. It is important when seeing patients with hip or groin pain for which no clear reason can be found to consider these diagnoses or send the patients to a hip specialist.

As with all new concepts, it is difficult to prove that extra-articular hip impingement really exists. Cam and pincer impingement are finally recognized as entities that are treatable and are seen by every orthopedic surgeon and not just the hip enthusiasts. Now we hope for the same clarification for IFI, SSI and pelvitrochanteric impingement. Previous research on diagnostics and anatomical deformations concludes that it is very plausible to say that IFI, SSI and pelvitrochanteric impingement do indeed exist [20,41,42].

For AIIS impingement, there is a consensus on classification based on CT imaging [20]. Also, a very recent study concludes that MRI is a useful method for assessing the osseous and soft tissue abnormalities associated with IFI and also for quantifying anatomical variations in pelvic morphology that can predispose to IFI [42].

CONCLUSIONS

Several disorders around the hip can cause similar complaints. Therefore, we plead for a standardized description and classification. This includes a thorough medical history, assessment of symptoms, clinical examination, standard AP pelvic radiographs and frog-leg lateral radiographs. If necessary, an additional MRI or intra-articular injection of Marcaine can help in making the right diagnosis. If one suspects a patient of having a rare type of extra-articular impingement, this paper provides relevant information regarding clinical examination, diagnostic tests and treatment options.

There is much to gain if hip impingement is diagnosed early, especially in young and athletic patients. In medicine, in general, you can only make the diagnosis you were considering to begin with. So, unless you have recognized the more uncommon types of hip impingement, you are unlikely to diagnose them.

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CHAPTER 4

4

Chapter 4

THE INFLUENCE OF PAIN CATASTROPHIZING AND CENTRAL SENSITIZATION ON THE REPORTED PAIN AFTER HIP ARTHROSCOPY

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ABSTRACT

Purpose; This study was conducted to investigate whether the pain catastrophizing scale (PCS) and the central sensitization inventory (CSI) are predictive factors for the reported pain after hip arthroscopy.

Methods; A total of 37 patients undergoing hip arthroscopy for femoroacetabular impingement syndrome and labral tears were prospectively enrolled. All patients completed the PCS and CSI before hip arthroscopy. Postoperative pain was measured with the numeric rating scale (NRS) weekly the first 12 weeks after surgery by electronic diary.

Results; At baseline, univariate analyses showed that both the CSI and PCS were significantly associated with the NRS outcome ($p < 0.01$). During 12 weeks follow-up, a significant decrease on the NRS was observed ($p < 0.01$). Univariate analyses showed that both the CSI and PCS were significantly associated with the NRS during follow-up. Multivariate mixed model analysis showed that only the PCS remained significantly associated with the NRS outcome with a β of 0.07 (95% CI 0.03–0.11, $p < 0.01$).

Conclusion; Results indicate that both the PCS and CSI are associated with the reported postoperative pain after hip arthroscopy.

The PCS and CSI may be useful in daily practice to identify patients that possibly benefit from pain catastrophizing reduction therapy (e.g. counseling) prior to surgery.

INTRODUCTION

Postoperative pain after hip arthroscopy is usually measured as numeric rating scale (NRS) and is commonly used as outcome after surgery [17]. Although measuring of postoperative pain with the NRS is well validated there are several patient-related factors that might influence the reported postoperative NRS score. In current literature, several factors are described as being risk factors for negative outcome after surgery, for example: female gender, increasing age, duration of symptoms before surgery, presence of pre-operative osteoarthritis and an increased BMI [3, 16, 28].

Other non-orthopedic factors, such as patient mental health and psychological state, might influence the reported postoperative pain as well [10, 12, 27]. One of those factors might be central sensitization (CS) in which an abnormal enhancement of the pain mechanism may be present involving the central nervous system [20, 22]. Central sensitization is defined as an increased sensitivity of the central nervous system [5]. Central nervous system hyper excitability is associated with various symptoms for example pain. Basically, it can be said that processing of nociceptive inputs can differ between individuals resulting in a different perception of pain [20, 22]. For example, CS is a reported risk factor for persistent pain, patient dissatisfaction and lower quality of life in patients undergoing total knee arthroplasty [15]. For measuring symptoms related to CS the central sensitization inventory (CSI) is used and a cut-off value of 40 out of 100 points is determined to identify patients with central sensitization syndrome (CSS) [19, 21, 22].

Another non-surgical factor that may be of influence on the reported postoperative pain is pain catastrophizing (PC). If PC is present, the patient has a tendency to magnify the threat value of a pain stimulus and to feel helpless in the presence of pain, also controlling pain-related thoughts can be a problem [24, 29]. PC has shown to be related to higher levels of pain and suffering and worse outcome after musculoskeletal surgery [1, 8, 13, 23]. PC is usually measured and validated with the pain catastrophizing scale (PCS) [29].

If factors, such as PC and CS, play a role in postoperative pain there might be a reason for routine pre-operative measuring both scores. The aim of this study is to investigate the role of PC and CS on the reported pain after hip arthroscopy and the hypothesis is that both CS and PC are of influence on the reported pain after hip arthroscopy.

MATERIALS AND METHODS

All included patients were part of a trial for which the study protocol was approved by the medical ethical committee (NL55669.048.15). Inclusion criteria for our current study were a confirmed diagnosis of Femoroacetabular Impingement Syndrome (FAIS), age between 18 and 65 years and a completed CSI and PCS. FAIS is considered abutment of the proximal femur to the acetabular rim [2]. Diagnosis of FAIS was made with plain radiographs and MRI by measuring the alpha angle, lateral centre-edge angle and measuring a possible cross-over sign. Exclusion criteria were previous hip arthroscopy or hip surgery, indications for hip arthroscopy other than FAIS and/or a BMI > 35.

All patients were operated by a single orthopedic surgeon (D.H) with good hip arthroscopy experience (> 1000 procedures performed and > 150 annually). Procedures were performed in either a general hospital or a private orthopedic clinic. A total of 37 patients completed both the PCS and CSI and were included in our current study. Baseline characteristics are shown in Table 1.

OUTCOME

Pain was measured using a Numeric Rating Scale (NRS pain) and all patients were asked to complete a Central Sensitization Inventory (CSI) and a Pain Catastrophizing Scale (PCS) before surgery. The NRS was measured pre-operatively at baseline and weekly after surgery until 12 weeks post-operatively (by electronic diary). The outcome ranges between 0 and 10 where 0 means no pain and 10 worst possible pain. The NRS is a validated tool for measuring pain [6]. The CSI is a validated tool that is used to identify patients who have symptoms that may be related to CS [19]. The questionnaire consists of 25 questions and a score between 0 and 100 (best to worst) can be reached. A score of more than 40 indicates the presence of central sensitization [20]. PC was measured with the pain catastrophizing scale (PCS). The questionnaire which measures three components of pain catastrophizing being rumination, (e.g. "I can't stop thinking about how much it hurts"), magnification (e.g. "I'm afraid that something serious might happen") and helplessness (e.g. "There is nothing I can do to reduce the intensity of my pain") [29]. The PCS is a well-validated 13-item questionnaire and patients can answer on a 0-to-4 Likert scale (0 = "not at all" and 4 = "all the time") [29]. The total score ranges between 0 and 52 and a total PCS score of 30 represents clinically relevant level of catastrophizing [29]. The higher the score, the more catastrophizing is present.

STATISTICAL ANALYSIS

Baseline and clinical characteristics are described as means with standard deviations (SD) in case of continuous variables and frequencies with accompanying proportions in case of categorical variables. The association of potential risk factors for pain (CSI, PCS, age, gender, BMI) at baseline and 12 weeks, and during follow-up (weeks) was assessed using linear regression analysis and mixed model analysis for repeated measures, respectively. Initially, univariate analyses were performed to identify potential risk factors. Factors that were significantly associated with the outcome (adjusted significance level of 0.10), were entered in a multivariate model (significance level 0.05). Adjustments for baseline values of the NRS were performed where appropriate. Fixed effects estimate with their 95% confidence intervals are presented (95% CI). A p value < 0.05 was considered statistically significant.

No power analysis was performed since there were no data from previous studies to power on.

Table 1: *Baseline and clinical characteristics (n = 37). NRS numeric rating scale, CSI central sensitization inventory, PCS pain catastrophizing scale, SD standard deviation*

Demographics	
Age (years), mean (SD)	35.4 (10.4)
BMI, mean (SD)	23.6 (2.8)
Gender, n (%)	
Male	23 (62%)
Female	14 (38%)
Operation details	
CAM, n (%)	15 (41%)
Pincer, n (%)	20 (54%)
Labral repair, n (%)	20 (54%)
Psoas lengthening, n (%)	2 (5%)
PROMs	
NRS_{pain}, mean (SD)	4,0 (2.5)
CSI, mean (SD)	30.5 (17.1)
PCS mean (SD)	16.6 (11.3)

RESULTS

At baseline and 12-week follow-up, univariate analyses showed that gender and both the CSI and PCS were significantly associated with the NRS outcome ($p \leq 0.01$).

Multivariate analysis, however, revealed only the PCS as significantly being associated with the NRS with β-values of 0.09 ($p = 0.01$) and 0.07 ($p = 0.01$), respectively (Table 2).

During 12-week follow-up, univariate analysis showed that gender, CSI, PCS were significantly associated with the NRS. Multivariate mixed model analysis showed that only the PCS remained significantly associated with the NRS outcome with a β. of 0.06 (95% CI 0.01–0.10, $p = 0.01$) (Table 2). Overall, decrease of the NRS at 12-week follow-up was 3.1 points (95% CI 2.4–3.8). Twelve patients (32%) reported a CSI > 40 and three patients (8%) a PCS > 30 points.

Additional univariate analysis using a cut-off value of 40 for the CSI showed that during 12-week follow-up, patients with a CSI > 40 scored on average 1,47 (95% CI 0.53–2.4) points higher on the NRS than patients with CSI < 40 ($p < 0.01$) (Fig. 1). This analysis was not performed for the dichotomized PCS as there were only three patients having a PCS > 30.

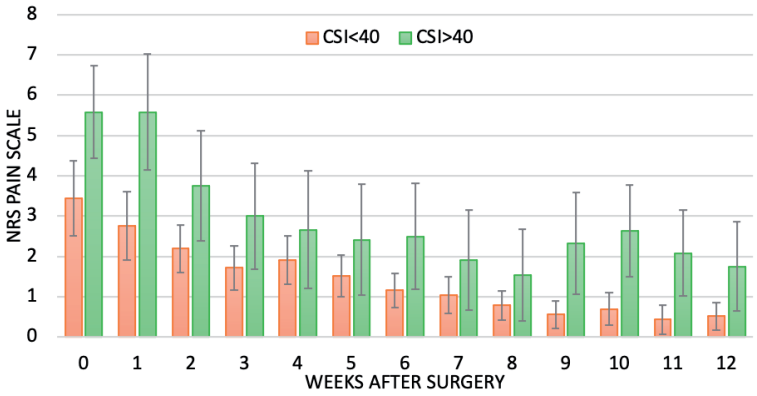

Figure 1: *Mean (95% CI) NRS scores during 12-week follow-up stratified for the CSI (cut-off value 40). NRS numeric rating scale, CSI central sensitization inventory. Error bars represent 95% confidence interval*

Table 2: *Univariate and multivariate analyses of factors associated with the NRS pain at baseline, at 12 weeks and during follow-up (0–12 weeks).*

Univariate analyses								
Baseline			At 12 weeks			0 to 12 weeks		
	ß (95%CI)	p-value		ß (95%CI)	p-value		ß (95%CI)	p-value
						Follow up (weeks)	-0.24 (-0.27; -0.21)	<0.01
Age	-0.13(-0.09; 0.07)	n.s	Age	0.01 (-0.04; 0.05)	n.s	Age	0.01 (-0.04; 0.05)	n.s
Gender	2.28 (0.88; 3.68)	<0.01	Gender	-0.80 (-1.64; 0.03)	n.s	Gender	-0.80 (-1.64; 0.03)	0.06
BMI	0.11 (-0.14; 0.36)	n.s	BMI	-0.03 (-0.17; 0.11)	n.s	BMI	-0.03 (-0.17; 0.11)	n.s
CSI	0.07 (0.03; 0.12)	<0.01	CSI	0.04 (0.01; 0.07)	0.01	CSI	0.04 (0.01; 0.07)	<0.01
PCS	0.12 (0.06; 0.18)	<0.01	PCS	0.08 (0.05; 0.12)	<0.01	PCS	0.08 (0.05; 0.12)	<0.01
			NRS-BL	0.19 (0.04 to 0.34)	0.01	NRS-BL	0.32 (0.18 to 0.46)	<0.01
Multivariate analyses								
Baseline *			At 12 weeks#			0 to 12 weeks		
	ß (95%CI)	p-value		ß (95%CI)	p-value		ß (95%CI)	p-value
						Follow up (weeks)	-0.25 (-0.28; -0.22)	<0.01
Gender	0.72 (-0.71; 2.15)	n.s				Gender	-0.01 (-0.88 to 0.85)	n.s
CSI	0.04 (-0.01; 0.08)	n.s	CSI	0.01 (-0.19 to 0.04)	n.s	CSI	0.01 (-0.02 to 0.04)	n.s
PCS	0.09 (0.02; 0.16)	0.01	PCS	0.07 (0.02 to 0.11)	0.01	PCS	0.06 (0.01 to 0.1)	0.01
			NRS-BL	0.09 (-0.12 to 0.29)	n.s	NRS-BL	0.14 (-0.07 to 0.36)	n.s

NRS numeric rating scale, CSI central sensitization inventory, PCS pain catastrophizing scale, NRS-BL Numeric Rating Scale at baseline, n.s not significant
**r2 = 0.40*
 # r2 = 0.44

DISCUSSION

The most important finding of the present study is that the pain catastrophizing scale (PCS) was significantly associated with pain outcome at baseline, at 12 weeks as well as during 12-week follow-up in patients who had undergone hip arthroscopy. The central sensitization inventory (CSI) was only significantly associated with pain outcome after univariate analyses, and showed that patients with possible central sensitization, based on the cut-off value of 40 points, reported overall 1.5 points higher on the NRS compared to patients with a CSI < 40.

These results imply that the PCS was more strongly associated with pain outcome than the CSI. It is however debatable how much clinical significance the PCS has with only a β of 0.06 meaning that for every point on the PCS patients reported 0.06 point higher on the NRS. The minimal clinical important change of the NRS is on average 1 point or 15% decrease in reported NRS [26].

There are some factors that are known to have a negative effect on the outcome after hip arthroscopy. These factors include increasing age, female gender and/or higher BMI [16, 28]. In our current study, we did not find any association between these factors and the outcome but this could have been caused because of the small sample size. Since no sample size calculation was performed for this study, the study could also be underpowered to detect the effect of the CSI.

With respect to the dichotomized CSI, the difference of 1.47 points on the NRS with patients with CSI < 40 could indicate a clinically relevant effect [26]. As the variation of the PCS was too small to categorize patients as pain catastrophizing (n = 3), this analysis could not be performed for the PCS. There is not much literature regarding the CSI and its effect on pain after hip arthroscopy. There are some papers that suggest a correlation between central sensitization and lower outcomes (or chronic pain) after total knee replacement surgery [18, 30].

In the paper of Jun Koh et al. the authors state that patients with pre-operative central sensitization show limited benefit of total knee arthroplasty compared to non-central sensitization patients [15]. A recent study by Dumont et al. shows that patients with FAIS and/or a diagnosis of depression or anxiety have higher levels on the pain catastrophizing scale [9]. In patients undergoing total knee arthroplasty, the level of pain catastrophizing is associated with higher postoperative pain, lower quality of life and lower patient reported outcomes after surgery [4, 14, 25]. Pain catastrophizing can be modified and is under influence of several factors, such as surgery, physical therapy, cognitive behavioral therapy and pharmacotherapy [11].

Surgical treatment itself can be a reason for a decrease in pain catastrophizing but it is important to realize that there is a group of patients that might benefit from pre-operative counseling, physiotherapy or even pharmacotherapy [11]. There is literature that shows a significant decrease in pain catastrophizing after a cognitive behavioral therapy program prior to orthopedic surgery [7]. These lower pre-operative pain catastrophizing scores resulted in lower postoperative pain and higher patient reported outcome scores after surgery [7].

Patient understanding and patient selection is important in the goal to achieve satisfying results after hip arthroscopy. The PCS and CSI may be of use in the pre-operative setting for measuring possible pain catastrophizing and identify those patients with high levels of pain catastrophizing or central sensitization. Both the PCS and CSI questionnaires are easy to use in daily practice and can give the orthopedic surgeon extra tools for identifying those patients that may benefit from pain catastrophizing reduction therapy (e.g. counseling) prior to surgery.

This study has some limitations: a small sample size, a small variation of the PCS and no results for the group of patients with a PCS > 30. The small sample size may have caused some instability in our results and a larger sample size would be necessary for correction of confounders to identify predictors for the NRS outcome.

CONCLUSION

Results of this study show that both the PCS and the CSI are associated with the NRS reported pain at baseline and 12 weeks and during follow-up after hip arthroscopy.

Unfortunately, this study has a small sample size and future research is needed to detect if these results hold and whether treating central sensitization or pain catastrophizing might improve indications and outcome after surgery.

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PART 2

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Part 2

OPTIMISING OUTCOME

CHAPTER 5

5

Chapter 5

PERIOPERATIVE PAIN MANAGEMENT IN HIP ARTHROSCOPY; WHAT OPTIONS ARE THERE?

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ABSTRACT

Hip arthroscopy is a fast-growing orthopedic field of expertise. As in any field of surgery adequate postoperative pain management regimes are of utmost importance. The purpose of this review is to provide an overview of current knowledge on anesthetic options for perioperative pain management for hip arthroscopy.

We searched the Pubmed/Medline and Embase database for literature and included 10 studies for our analysis. Because of the variety of pain scales and different ways of measured pain no meta-analysis could be performed and a descriptive review is performed.

There are several types of pain regimens that can mostly be divided in two groups: local anesthetics and nerve blocks. Included studies show a rather large variation in reported visual analogue scale scores, post anesthesia care unit admission time and opioid usage. There are several anesthetic options available for hip arthroscopy. Different studies use different dosages, anesthetic regimens and different protocols; this partly explains the differences between studies with similar techniques. Peripheral nerve blocks seems promising but regarding current literature no clear recommendation can be made about what the best perioperative pain management option is, an overview of all reported techniques is given.

INTRODUCTION

In recent decades hip arthroscopy gained popularity and the number of procedures performed increase every year by as much as 233% between 2007 and 2011 [1–3]. This is due to improved techniques [4] and the widening range of indications, such as femoroacetabular impingement, labral tears, chondral injuries, loose bodies, osteonecrosis and septic arthritis [5]. Hence, adequate postoperative pain management after these procedures gains relevance also. As with almost all relative new operation techniques it is not quite clear what the optimal perioperative pain protocol is.

There is a wide variation of reported pain scores after hip arthroscopy procedures. A study by Ward et al. [6] report of 90% of all patients experience moderate to severe pain after hip arthroscopy defined as a pain score of 7 or more on the visual analogue scale (VAS). Lee et al. [7] makes notice of even higher VAS scores (between 8 and 10) in the post anesthesia care unit (PACU). In a randomized trial of Zhang et al. [8] direct postoperative mean PACU pain scores are also above 7. These scores are considerably very high and consequently, higher VAS scores require more opioids that increase the incidence of postoperative nausea and vomiting. This can prolong hospital stay and cause unplanned re-admissions [9, 10]. Contradictory to these high pain scores is a study by Baker et al. [11], they report of a mean maximum VAS score of 2.4 (SD 2.9) in the PACU.

Pain after hip arthroscopy arises due to several factors. Perhaps the most logical division to make is to divide in two regions. First the intra-articular compartment where pain originates from the joint capsule (capsulotomy), a repaired labrum or bony resection. Outside the joint itself pain can be caused by traction; pain can originate from the portal tracts and possibly from extravasation of irrigation fluids through the capsulotomy that lead to soft tissue swelling. In the extra-articular compartment pain prevention can exist of lowering the pump pressure since higher fluid infusion pressure is strongly correlated with postoperative pain after hip arthroscopy [12]. Furthermore, lowering swelling of the upper leg and minimizing traction time positively influences postoperative pain [12]. The anesthesiologist can facilitate this by providing good muscle relaxation and keeping the blood pressure as low as possible. The pain caused by the intra-articular structures is more difficult to control because this is the basic work that needs to be done to make the surgical procedure successful.

Different parts of the hip joint capsule have different sensory innervations; the femoral nerve innervates the anterior part of the hip joint; the obturator nerve gives branches to the anteromedial part and the sciatic nerve provides innervation to the posterior part of the joint [13]. This innervation of the hip joint provides multiple anesthetic options; however, the best strategy remains unclear.

The aim of this systematic review is to provide an overview of the current scientific knowledge on perioperative pain management options in hip arthroscopy.

MATERIALS AND METHODS

INCLUSION CRITERIA

TYPES OF STUDIES

The search of the literature performed for this review was limited to published original reports concerning the perioperative pain regimens in hip arthroscopy.

Studies from levels of evidence I to IV were included. Abstracts from scientific meetings, unpublished reports, case reports and review articles were not included.

TYPES OF PARTICIPANTS

Inclusion was limited to articles on male and female adult humans undergoing hip arthroscopy. No limitation on the reason for hip arthroscopy was made.

TYPES OF INTERVENTION

All pain regimens, including peripheral nerve blockade, local anesthesia or pain medications used to treat perioperative pain around hip arthroscopy were included for this study.

TYPES OF OUTCOMES MEASURES

Our primary outcome is pain measurement, reported as a numerical rating scale or VAS score. Registration of PACU time and measurement of opioid consumption are secondary outcomes. The minimum criterion for inclusion of the trial in the review was the adequate reporting of at least one of the outcome variables. Information regarding other outcome measures and adverse events was extracted and analyzed when feasible.

SEARCH STRATEGY FOR IDENTIFICATION OF STUDIES

A research protocol was developed as described by Wright et al. [14], and used throughout the study process. This protocol was not registered. A literature search was performed throughout the Pubmed, Medline (Ovid) and Embase database on the 18th of August 2015. The search was independently performed by two authors (N.H.B. and D.H.). When using the following search terms: [(nerve block OR pain/diet therapy OR pain/drug therapy OR pain/prevention and control OR pain/therapy OR pain management OR analgesics) AND (arthroscopy) AND (hip OR hip joint)].

The references of retrieved publications were also manually checked to add studies potentially meeting the inclusion criteria and missed by the electronic search. Papers outside the English language were considered if translation was possible.

We initially found 240 papers of which 17 were included for full text analysis. Of these papers 7 were excluded from final analysis for the following reasons: excluded 2 because of no reported outcomes, 2 because of no intervention described and 3 because of not specifically hip arthroscopy patients.

The remaining 10 studies were included for analysis (Fig. 1).

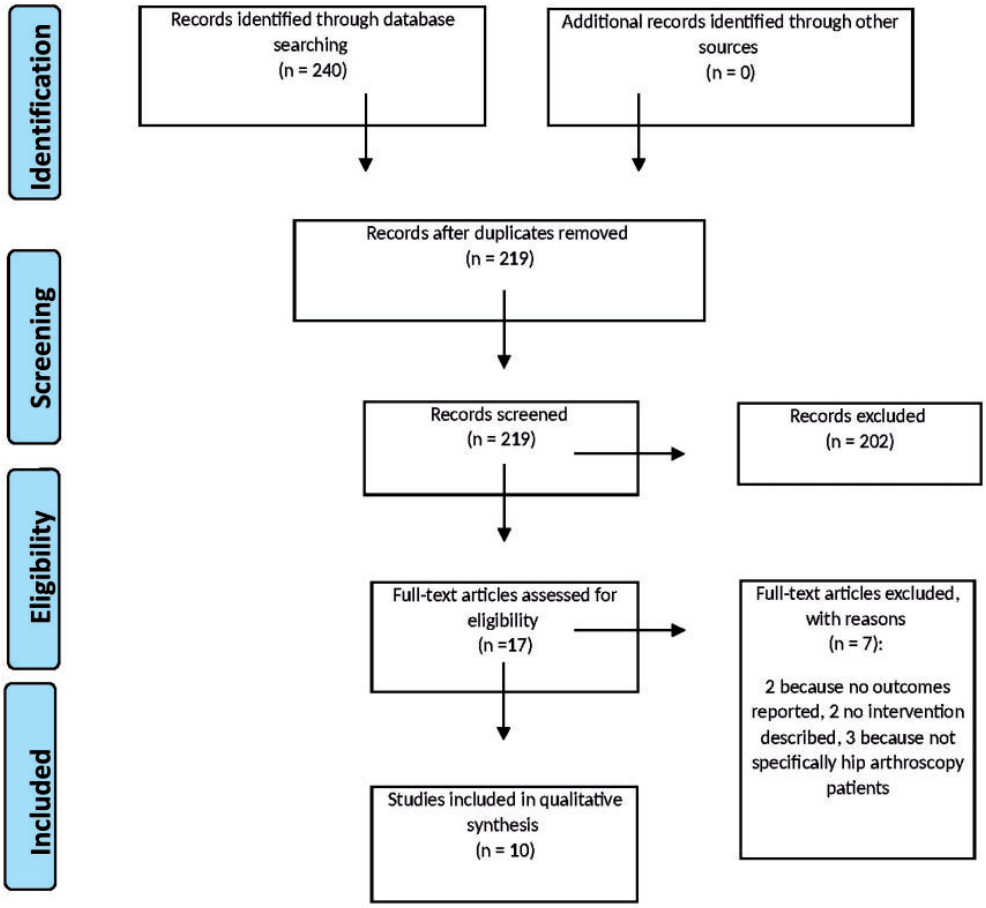

Figure 1: *Prisma flow chart*

RESULTS

Of the 10 studies included for analysis 5 are randomized controlled trials (RCTs) in which several techniques are evaluated (Table I). Because the various RCT's use different scales and measured pain differently it was impossible to pool the data for a meta-analysis.

LOCAL ANESTHETIC INFILTRATION

Intra-articular bupivacaine (injection of 20 ml 0.25% bupivacaine (50 mg) resulted in significant lower mean VAS scores and a decreased use of rescue medication in the first 20 h postoperatively when compared to placebo (injection of 20 ml 0.9% NaCl solution) in a small study of 26 patients [15]. Unfortunately, no power calculation was performed in this trial.

When comparing intra-articular bupivacaine versus portal infiltration with bupivacaine, postoperative VAS scores at 1 and 2 h were comparable [16].

The RCT of Baker et al. [16] was powered based on the lowest detectable change in VAS (1.3) and was calculated that 50 patients were required to observe a statistically significant difference (power 0.8, α 0.05). Because of gender imbalance they included eventually a total of 73 patients. In this trial patients received either 10 ml 0.25% bupivacaine intra-articular after shutting of fluid irrigation through one of the arthroscopic cannulas, or 10 ml 0.25% bupivacaine injected with an 18-gauge needle evenly spread between the portals. At 6 h postoperatively significant lower VAS scores were reported in the portal group (P.0.0036). Although having lower VAS scores, the portal group required significant more intravenous morphine in the immediate postoperative period (2.33 mg of morphine versus 0.57 mg morphine, P.0.036).

In a retrospective series by the same researchers 85 patients were assessed in whom 10 ml 0.5% bupivacaine was injected into the joint after surgery [11]. In this retrospective study the mean VAS at discharge from the recovery room was 1.4/10. In this paper no separate VAS scores the first hours after surgery were measured or recorded [11].

PERIPHERAL NERVE BLOCKS

In a study by Ward et al. [6] 40 patients were to receive either morphine or a femoral nerve block postoperatively if their VAS score was 7 or higher. In total 36 of 40 patients reported a VAS of 7 or higher; a remarkable high number that indicates general anesthesia was insufficient for 90% of these patients. No power analysis was performed in this trial.

A single anesthesiologist using an ultrasound probe and a nerve stimulator performed all femoral nerve blocks. With a 21-gauge needle 25 ml of 0.25% bupivacaine with 1:200 000 epinephrine was administered.

Of the 20 patients who received femoral nerve blocks 18 were satisfied with their anesthesia compared to 14 out of 16 in the morphine group. The femoral nerve block patients stayed in the PACU for shorter times (177.85 min ± 17.34 versus 216.00 min ± 19.48, P<0.0001) and suffered less postoperative nausea (10% versus 75%, P<0.001) after surgery than those who received intravenous morphine. VAS scores after the intervention were not reported.

Dold et al. [20] published a retrospective review of 96 patients, of which 40 received general anesthesia and 56 patients a femoral nerve block preoperatively. A staff anesthesiologist using ultrasound guidance performed all block procedures. Between 15 and 25 ml of ropivacaine (0.33– 0.75%) was injected to achieve circumferential spread around the femoral nerve. Mean pain scores were significantly lower 60 min postoperatively in the block group (2.48 versus 3.68, P 0.02). Patients in the femoral nerve block group received a significantly lower total intraoperative and postoperative morphine-equivalent dose (2.04 mg versus 4.0 mg, P.0.025). In the block group mean time to PACU discharge was 85,96 min ± 29.79 versus 81,53 min ± 26.07) for the no block group (P.0.44).

Two independent series reviewed the effect of a fascia iliaca blockade (FIB). In a case series by Potter et al. [19], 53 patients received a fascia iliaca block and 54 patients received general anesthesia. Fascia iliaca nerve blocks were performed under ultrasound guidance by specialty-trained regional anesthesiologists. A 22-gauge needle was positioned 1 cm lateral of the femoral nerve and 30 ml of 0.25% bupivacaine with 5mcg/ml of epinephrine.

Expansion of the tissue plane and local anesthetic spread around the femoral nerve was visualized with ultrasound to confirm proper placement of the block.

In the fascia iliaca block group initial PACU VAS scores were significantly higher than the no block group (7.2 ± 0.3 versus 5.5 ± 0.4, P 0.001), however the fascia iliaca block group showed a significantly more dramatic decrease in VAS scores during PACU admission (-4.3 ± 0.2 versus - 2.1 ± 0.3, P<0.0001). At discharge of the PACU there was no significant difference in VAS between the two groups (2.8 ± 0.3 versus 3.4 ± 0.3, P 0.15).

Opioid use measured in morphine equivalent dose in the PACU was the same in both groups (4.4 mg ± 0.6 versus 4.4 mg ± 0.6, P 0.98).

Krych et al. [18] included 30 patients who received a fascia iliaca block prior to surgery. There was no control group. Under ultrasound guidance a 22-gauge needle was advanced to enter the potential space between the iliacus muscle and the fascia iliaca. At this position 40 ml of 0.25% bupivacaine with 1:200 000 epinephrine was injected. Furthermore, all patients received additionally multimodal analgesics e.g. 10 mg i.v. ketamine and 15 mg i.v. ketorolac. Patients reported a mean VAS score of 3.56 ± 2.3 in the post-operative recovery room. Mean VAS scores were measured the first 5 days postoperatively, scores ranged between 4.76 ± 2.5 (Day 0) and 3.46 ± 1.9 (Day 5). Pain scores were measured at 6.00 p.m. on Day 0, it is not mentioned what the time was when patients underwent surgery.

Regarding their postoperative pain control 20 patients (67%) were very satisfied and 10 patients (33%) were satisfied. Time to discharge from the PACU was not measured in this study; no complications were reported in this study.

In a RCT of 82 patients, YaDeau et al. [17] administered a LPB in 41 patients versus combined spinal epidural anesthesia in 41 patients. In this trial, an adequate sample size/ power analysis calculation was performed and indicated 40 patients per group (two-sided α 0.05, β 0.20). Control patients were prepared for a LPB but no needle was inserted.

LPB was performed for LPB patients after sedation and a 21-gauge needle was inserted. After obtaining quadriceps stimulation at<0.5 mA, 30ml 0.25% bupivacaine with 1:200 000 epinephrine was administered.

Mean PACU pain scores in rest were significantly lower in the block group than the combined spinal epidural group (3.3 ± 2.2 versus 4.2 ± 1.8). They recorded no difference in PACU analgesic use, PACU pain during movement or patient satisfaction. Furthermore, they recorded no differences in pain scores, patient satisfaction or total analgesic use post discharge.

Schroeder et al. [21] determined the effect of an LBP versus general anesthesia in a retrospective series of 236 patients. Lumbar plexus blocks were performed in a room dedicated to regional anesthesia techniques. Following skin analgesia with 1% lidocaine a 21-gauge needle was inserted and a current was applied via a nerve stimulator. The needle was manipulated until a current of 1.0mA or less was able to elicit a contraction of the ipsilateral quadriceps muscle. 20–30 ml of 0.5% ropivacaine with 3mcg/ml epinephrine was administered. 118 patients were included in the LPB group and matched to 118 patients in a no block group.

In the block group peak PACU pain scores were significantly lower than the non-block group (5.0 (2.0–6.0) versus 5.3 ± 0.2, P 0.023, scores given as median). PACU admission time was also significant lower in the block group (217.5 min (175.5–264.5) versus 240 min (183.5–299.5), P 0.044, scores given as median).

Perioperative opioid administration was significant lower in the block group than the non-block group [5.0 mg (2.5–7.0) versus 7.5 mg (5.0–10.0) P<0.0001, scores given as median].

Zhang et al. [8] performed a RCT in which 27 patients received 200 mg Celecoxib 1 h preoperatively and 26 patients received 200 mg of a placebo. No power calculation was done in this study. VAS scores at 12 h (7.65 versus 8.93) and 24 h (5.13 versus 7.45) postoperatively were significantly lower in the Celecoxib group (P<0.05).

Medication usage was also significantly lower in the Celecoxib group (2.56 pills versus 4.35 pills, P<0.05). No difference was found in average time to discharge of the recovery room: 147 min for the Celecoxib group versus 152 min for the placebo group (P>0.05).

Table 1: *All included studies*

Study	Type	Group 1	N	Group 2	N	Outcomes
Morgenthaler 2007	RCT	Intra-articular bupivacaine	13	Placebo	13	VAS and rescue medication
Baker 2011	RCT	Portal infiltration	33	Intra-articular infiltration	40	VAS and rescue medication
Ward 2012	RCT	Femoral nerve block	20	General anesthesia	20	PACU time, nausea, operation time
YaDeau 2012	RCT	Lumbar plexus nerve block	41	General anesthesia	41	VAS, rescue medication, nausea/vomiting, hospital stay
Zhang 2013	RCT	200mg Celecoxib	27	Placebo	26	VAS and rescue medication
Krych 2014	Prospective series	Fascia iliaca block	30	No control group		VAS, nausea, opioid use, patient satisfaction
Potter 2014	Prospective series	Fascia iliaca block	53	General anesthesia	54	VAS, PACU time, opioid use
Dold 2014	Retrospective review	Femoral nerve block	56	General anesthesia	40	VAS, PACU time, opioid use
Baker 2010	Retrospective chart review	Bupivacaine intra-articular	85	No control group		VAS, opiate requirement
Schroeder 2013	Retrospective review	Lumbar plexus block	118	General anesthesia	118	Peak PACU pain, PACU time, escape medication

DISCUSSION

This review shows there are several perioperative anesthetic treatment options with similar results regarding VAS scores and mean time to discharge from the PACU (Figure 2 and 3). Unfortunately, pooling of the data is not possible because there is too much variation in pain scale recordings and analgesic use between the different studies. Figure 2 shows great variation in PACU discharge time, even between studies with the same technique.

INFILTRATION TECHNIQUES

A knee arthroscopy study shows that portal infiltration might be a good alternative for intra-articular infiltration regarding postoperative pain [22]. It is imaginable that pain after hip arthroscopy arises more from soft tissue swelling compared with knee arthroscopy; during hip arthroscopy traction is used and portals have to penetrate through a thicker soft tissue mass. In the only portal infiltration study included in this analysis, VAS scores were significantly lower 6 h after surgery compared with the intraarticular group, there was no difference in scores at 1 and 2 h after surgery.

Several studies reported the outcomes of intra-articular infiltration directly after hip arthroscopy [11, 15, 16]. Patients receiving intra-articular bupivacaine had significantly lower VAS scores compared to a placebo group. Unfortunately, separate VAS scores were not recorded over a longer period of time.

Previous knee arthroscopy studies investigated the effect of local joint injection with morphine or clonidine and showed improved results regarding pain scores after surgery [23, 24]. In a knee arthroscopy study measuring the effect of different types of intra-articular anesthetics, both groups with intra-articular levobupivacaine and tramadol or fentanyl showed significant better results than the levobupivacaine alone or control group [25].

Thus, the effect of intra-articular infiltration seems evident but the local anesthetic may also damage chondrocytes.

Studies by Chu et al. [26–28] show that bupivacaine can have toxic effects on chondrocytes. A recent in vivo canine study by Sherman et al. [29] reported that the viability of chondrocytes is significantly decreased after intra- articular injection of local anesthetic corticosteroids combinations.

Alternative to intra-articular infiltration of corticosteroids is the injection of magnesium. In a group of patients undergoing knee arthroscopy significant lower pain scores

were reported with the injection of magnesium compared to a placebo [30]. As to our knowledge no hip studies with magnesium are performed so far. Furthermore, an in vitro study performed by Baker et al. [31] compared chondrocyte cell viability after injection of local anesthetic (bupivacaine, levobupivacaine, lidocaine or ropivacaine) with and without adding magnesium sulfate. The addition of magnesium resulted in higher levels of cell survival compared with the local anesthetic alone. The risk of chondrotoxic damage induced by intra-articular infiltration seems plausible and one must weigh this to the benefit of relatively small changes in VAS scores. If local anesthetic is given it might be wise to add magnesium sulfate to reduce local toxic effects on chondrocyte cell viability [31].

The group of Zhang et al. [8] is the only group that investigated the effect of a COX-2 inhibitor. They recorded significant lower VAS scores in the Celecoxib group than the placebo group. Therapeutic effects are likely because of the selective inhibition of cyclooxygenase 2, while the toxic effects are induced by inhibition of cyclooxygenase 1. A selective cyclooxygenase 2 inhibitor could definitely play a role in a postoperative pain regimen since it shows better results in pain scores than placebo.

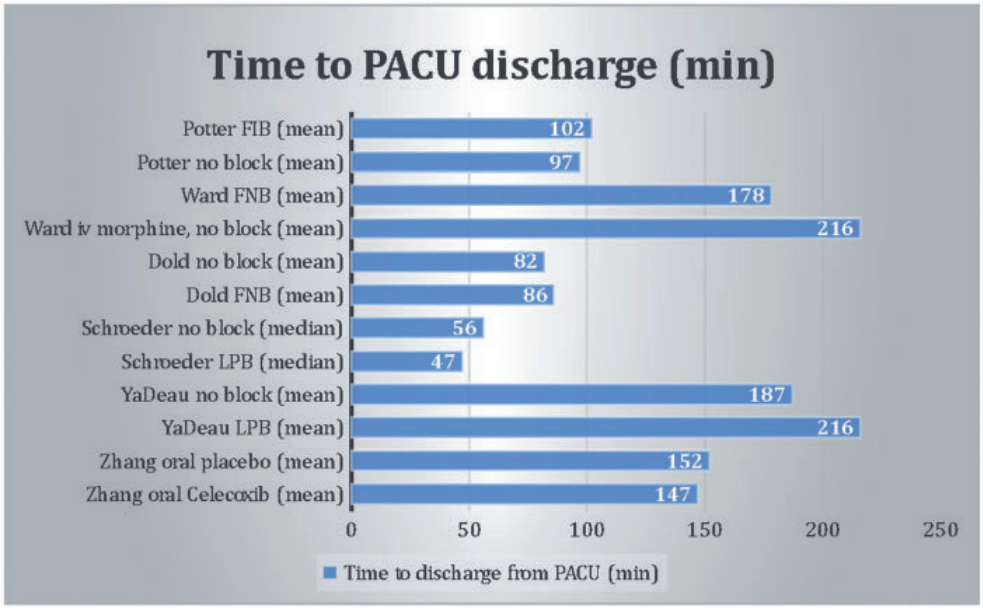

Figure 2: *Time to PACU discharge (minutes).*

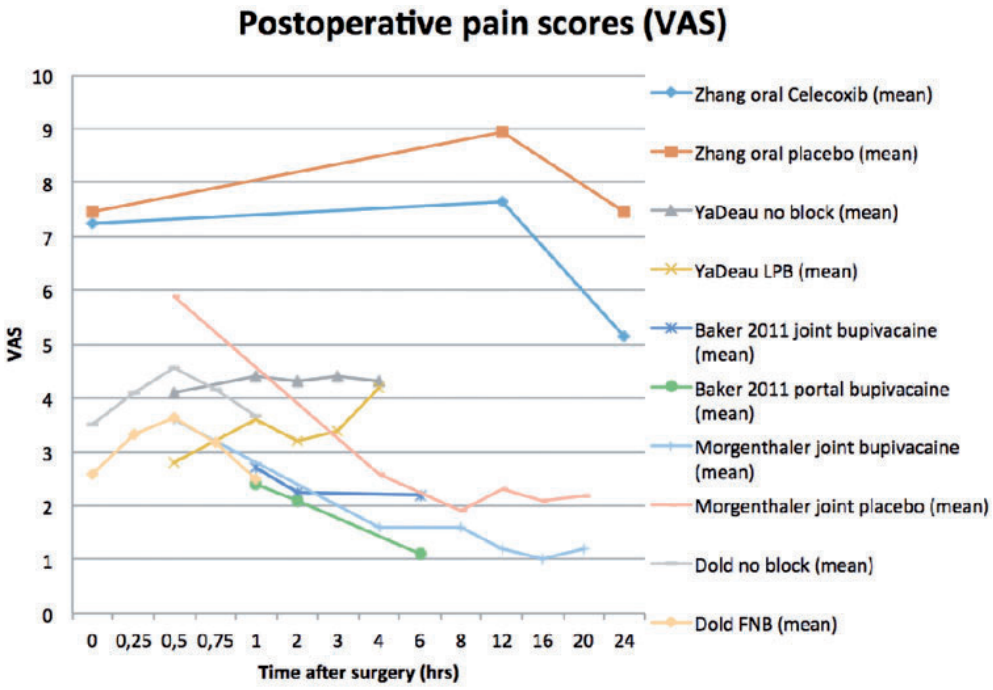

Figure 3: *Mean postoperative VAS scores.*

PERIPHERAL NERVE BLOCKADE

LPB for total hip replacement seems a promising technique to reduce postoperative pain adequately with a low rate of complications [33, 34]. In the study of YaDeau et al. [17], LPB significantly reduced pain scores in the PACU, it is questionable if this difference is clinically relevant since pain scores were similar in both groups 4 h after surgery. Schroeder et al. [21] reported in their retrospective review significantly lower immediate and peak PACU pain scores in the LPB group. Unfortunately, no separate VAS scores were measured over a longer period of time.

In a meta-analysis of hip surgeries, a LPB resulted in lowered pain scores 4–8 h after surgery compared to opioids alone. In that analysis no convincing evidence was reported to support LPB over spinal, epidural or general anesthesia. It is remarkable that there is a great difference in both LPB studies for measured time to PACU discharge while both performed more or less the same anesthetic procedure.

In Yadeau's group mean time to discharge was 216 min (±86) for the LPB patients, in Schroeder's study it was 47 min (39,5–62,0). Yadeau's study reports that patients were discharged following predetermined criteria, it is not mentioned what these criteria were. Schroeder's group does not mention PACU discharge criteria.

Paravertebral blocks might be a theoretical alternative offering some advantages over the LPB; it is a more simple technique, LPB is associated with some serious complications (epidural or spinal spread resulting in hypotension, retroperitoneal hematoma) and in contrast to the LPB the quadriceps muscle strength is maintained with a paravertebral block. A case-report suggests that L1-L2 paravertebral blocks might have a similar effect on postoperative VAS pain scores for hip arthroscopy patients [7, 35]. Overall, a paravertebral block might provide the patient with better options for early mobilization and possibly early same day hospital discharge although so far there are no clinical trials performed which support this.

The femoral, sciatic and obturator nerves all innervate the hip joint. However, the contribution of each nerve to postoperative pain after hip arthroscopy is unclear. The femoral nerve seems responsible for a major part of the innervation of the hip capsule [13]. A femoral nerve blockade (FNB) has already been identified and used as an adequate anesthetic technique for knee surgery [36, 37]. The use of a FNB for hip surgery improved pain control the first hours after surgery [38]. Dold et al. [20] reported lower pain scores in the FNB group 60 min after surgery. Total morphine dose in the PACU and maximal pain rating in the surgical day care unit were also significantly lower in the FNB group. This study lacked standard protocols, patients received different dosages and combinations of analgesics, antiemetic prophylaxis, and varying concentrations and volumes of local anesthetics were used.

Ward et al. [6] reported significantly less nausea, shorter PACU times and higher rates of satisfaction in their FNB group compared to intravenous morphine. Unfortunately, no VAS scores were reported after intervention and only a dichotomous yes or no was scored for patient satisfaction.

In the study of Ward et al. [6] a FNB was given if PACU pain scores were 7 or higher, in Dold's study patients received a pre-operative block. This might explain great postoperative differences in PACU pain scores between both studies. It might also be the reason for the rather large difference in mean time to PACU discharge, 85.96 min (± 29.79) in Dold's study versus 177.85 min (± 34) in Ward's group. Although promising, due to the methodological shortcomings it is hard to draw a definite conclusion on FNB for hip arthroscopy.

In femur fracture or total hip arthroplasty studies a FIB resulted in decreased pain scores and lower opioids consumption postoperatively after surgery [39–42]. In our analysis two studies evaluated the effect on pain scores of a FIB after hip arthroscopy. In the group of Krych et al. [18], 30 consecutive patients received a FIB and all patients left the hospital the same day of surgery, with mean Day 0 reported VAS scores 4.7. This study lacked a control group and multimodal analgesia was used; therefore, it cannot be said what the sole effect was of the FIB. In the study of Potter et al. [19], patients received a FIB postoperatively

in the PACU if they reported inadequate pain control. Therefore, it is logical that initial VAS scores in the PACU are higher in the FIB group, though the dramatic change in VAS scores seems promising. No pain scores the first hours after surgery were recorded and the lack of randomization is limitations of this study. We believe it is hard to recommend this technique based on the available data.

LIMITATIONS

Limitations of these studies: often case series, no control groups, randomization not clarified, methods poorly explained, small groups, different pain scores used, not always well specified nor time of measurement. VAS scores for shorter periods of time measured. Patient satisfaction measured as dichotomous outcomes. The included RCT's should be analyzed with care since 3 of the 5 comparative studies did not report any power analysis [6, 15, 8]. Only Baker et al. [16] and Yadeau et al. [17] performed an adequate calculation, where Baker et al. added a total of 23 patients for gender imbalance. We think the analysis of Yadeau is the most accurate and the other studies might be underpowered.

There is large heterogeneity in performed nerve blocks, different dosages and techniques, different patient groups and reported pain scores. Furthermore, different studies that investigate the same anesthetic technique, report large differences in PACU discharge time. It is imaginable that different institutions use different protocols and guidelines when a patient is ready for PACU discharge. This might explain the rather large difference in PACU admission time.

CONCLUSION

There is a wide variation in anesthetic techniques available for pain management after hip arthroscopy; some techniques can even be combined. Based on the available literature no clear recommendations on which technique to use can be made, because comparison of studies is impossible.

Future randomized trials are needed to evaluate the best pain management for hip arthroscopy. We recommend that future studies use validated VAS pain score registration at regular intervals, use standardized anesthetic block techniques and follow standard perioperative analgesic protocols.

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CHAPTER 6

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Chapter 6

CAPSULAR CLOSURE VERSUS UNREPAIRED INTERPORTAL CAPSULOTOMY AFTER HIP ARTHROSCOPY IN PATIENTS WITH FEMOROACETABULAR IMPINGEMENT, RESULTS OF A PATIENT-BLINDED RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: Hip capsular management after hip arthroscopy remains a topic of debate. Most available current literature is of poor quality and are retrospective or cohort studies. As of today, no clear consensus exists on capsular management after hip arthroscopy.

Purpose: To evaluate the effect of routine capsular closure versus unrepaired capsulotomy after interportal capsulotomy measured with NRS pain and the Copenhagen Hip and Groin Outcome Score (HAGOS).

Materials and methods: All eligible patients with femoroacetabular impingement who opt for hip arthroscopy (n = 116) were randomly assigned to one of both treatment groups and were operated by a single surgeon. Postoperative pain was measured with the NRS score weekly the first 12 weeks after surgery. The HAGOS questionnaire was measured at 12 and 52 weeks postoperatively.

Results: Baseline characteristics and operation details were comparable between treatment groups. Regarding the NRS pain no significant difference was found between groups at any point the first 12 weeks after surgery ($p = 0.67$). Both groups significantly improved after surgery ($p < 0.001$). After 3 months follow-up there were no differences between groups for the HAGOS questionnaire except for the domain sport ($p = 0.02$) in favour of the control group. After 12 months follow-up there were no differences between both treatment groups on all HAGOS domains ($p > 0.05$).

Conclusions: The results of this randomized controlled trial show highest possible evidence that there is no reason for routinely capsular closure after interportal capsulotomy at the end of hip arthroscopy.

Trial Registration

This trial was registered at the CCMO Dutch Trial Register: NL55669.048.15.

INTRODUCTION

Nowadays, hip arthroscopy is a proven and established technique to address intra-articular hip pathology.[1] The technique is still improving and evolving; a current topic of debate is how to address the hip capsule at the end of the procedure.

The hip capsule is comprised of 4 ligamentous structures described and named based on their anatomical position; iliofemoral ligament, pubofemoral ligament, ischiofemoral ligament and zona orbicularis.[2]

Several cadaveric studies have investigated the effect of a capsulotomy on the biomechanical properties of the hip. [3–7] Abrams et al. [3] reported that a T-capsulotomy leads to increased external rotation of the hip. Khair et al. [5] showed that complete closure of the hip capsule after capsulotomy results in restoration of biomechanical properties of the hip. The study of Baha et al. [7] found that repair of the capsule after interportal or T-shape capsulotomy restores the hip joint kinematics to near intact levels. This study stated that the hip capsule should be repaired routinely at the end of the procedure, especially after T-shaped capsulotomy. [7]

Despite the findings of these cadaveric studies there is much debate about what to do with the capsule after hip arthroscopy. A survey among orthopedic surgeons showed that 78% of the surgeons had the opinion that the decision to perform a capsular repair was case dependent. [8] A recent review by Riff et al. [9] showed a shift to more routinely repair of the capsule during the last years.

Studies from between 2009 and 2011 reported regular capsular repair in 7% of the cases, whereas studies from 2017 found 58% of the capsulotomies being routinely repaired. [9]

The effect of routine capsular repair on patient reported outcomes is still not completely clear; a retrospective review by Domb et al. [10] showed no improvement in outcomes after capsular repair comparing with unrepaired capsulotomy. This is in contrast with the cohort study of Frank et al. [11] which suggests improved outcomes after capsular repair after hip arthroscopy for FAI.

In a recent randomized trial by Economopoulos et al. [12] 3 different patient groups were compared; T capsulotomy without capsular closure, interportal capsulotomy without capsular closure and interportal capsulotomy with complete closure. In that paper they showed that complete capsular closure results in improved patient reported outcome and

surgical outcome, suggesting that complete capsular repair is the favorable capsular management technique. [12]

The aim of the current randomized controlled trial is to evaluate the effect of routine capsular closure versus unrepaired capsulotomy after interportal capsulotomy measured with the NRS pain and the Copenhagen Hip and Groin Outcome Score (HAGOS).

Primary hypothesis is that capsular repair results in less postoperative pain the first 12 weeks after surgery compared to capsulotomy.

Secondary hypothesis is that capsular repair results in better patient-reported outcome measures compared to capsulotomy measured with the HAGOS questionnaire.

MATERIALS AND METHODS

TRIAL DESIGN AND PARTICIPANTS

This study was designed as a prospective patient blinded randomized controlled trial and was conducted between June 2016 and October 2018. Study protocol was approved by the medical ethical committee (NL55669.048.15). All patients were operated by a single orthopedic surgeon with sufficient hip arthroscopy experience (>500 procedures performed and >150 annually). Procedures were performed in either a general hospital or a private orthopedic clinic. All patients between 18 and 65 years old, with a body mass index (BMI) <35 kg/m2, a good understanding of Dutch/English language and with intra-articular hip pathology who opt for primary hip arthroscopy for femoroacetabular impingement (FAI) or labral pathology were eligible for inclusion. FAI is considered abutment of the proximal femur to the acetabular rim. CAM lesions being the result of the aspherical contour of the head-neck junction and PINCER deformities being acetabular wall over coverage. [13] Diagnosis of FAI was made with plain radiographs and/or MRI by measuring the alpha angle, lateral centre-edge (CE) angle and measuring a possible crossover sign. Patients were excluded in case of: revision hip arthroscopy; extra-articular hip pathology; a documented systemic connective tissue disease or hypermobility; a CE angle <25°; prior hip surgery or a hip fracture in the past.

OBJECTIVES

Primary objective was to evaluate the effect of capsular repair compared to capsulotomy on early postoperative pain (in rest) the first 12 weeks postoperatively. Pain was measured by an 11-point Numerical Rating Scale.

Secondary objective was to evaluate the effect of capsular repair versus capsulotomy on patient-reported functional outcome scores measured with the Copenhagen Hip and Groin Outcome Score (HAGOS). [14]

Primary hypothesis was that capsular repair results in less postoperative pain the first 12 weeks after surgery compared to capsulotomy. Secondary hypothesis was that capsular repair results in better patient-reported outcome measures compared to capsulotomy.

SURGICAL TECHNIQUE

All patients were operated in the supine position and 2 or 3 portals were made by standard procedure. In all hips the capsulotomy was done by an interportal cut; we didn't perform any T-shaped capsulotomies meaning that the zona orbicularis is preserved in all cases. At the end of the procedure the hip joint capsule was completely repaired with 2 or 3 sutures by arthroscopic technique (Capsular Close Scorpion, Arthrex) (supplementary file 1).

With regard to capsular closing, we used 2 or 3 sutures since the paper by Chahla et al. [15] reported comparable biomechanical strength between 2 or 3 sutures and 1 suture is significantly weaker than 2 or 3. Capsular repair took around 15 minutes extra operating time. Standard sutures were used (fibrewire, Arthrex). In the control group, at the end of the procedure if all intra-articular hip pathology was addressed no further action was taken. Portal wounds were closed with stiches via standard protocol. No perioperative antibiotics were given and no drains were used postoperatively. For thrombosis prophylaxis all patients received 4 weeks postoperatively a low molecular weight heparin in a prophylaxis dose. To inhibit heterotopic bone formation all patients received 4 weeks diclofenac postoperatively.

Postoperative rehabilitation protocol consisted of the first 4 weeks no weight bearing, from week 5 patients were allowed to start weight bearing with elbow crutches. The first 6 weeks no rotational movements in the hip were allowed, starting in week 7 with passive and active rotational movement without resistance. In week 9 start cycling and rotational movement against resistance. From week 12 all restrictions were lifted. Rehabilitation protocol was exactly similar for both treatment groups.

STUDY PROCEDURES

Patients diagnosed with intra-articular hip pathology presenting at the outpatient clinic were screened for eligibility and asked to participate in the study. After 1 week they were contacted by a research assistant to confirm participation and sign informed consent. Preoperatively they completed the NRS for pain and the HAGOS questionnaire and after

surgery patients were asked to fill in the NRS pain scale weekly for 12 weeks starting 7 days postoperatively. This was done by use of a pain diary which was sent to the patients electronically. Furthermore, patients completed the HAGOS questionnaires at 12 and 52 weeks postoperative during regular visits to the outpatient clinic.

RANDOMIZATION

On the day of surgery, a clinical research assistant performed the randomization. This randomization was done with the use of a specially designed computer program.

The randomization was patient-blinded. The patient remained blinded until after the last follow-up.

SAMPLE SIZE

Sample size calculation was performed by use of Nquery (version 7.0) and was based on the primary outcome measure; NRS for pain. Based on a minimal relevant difference of 1 point, [16] a standard deviation of 1.8, [17] a power of 80% and an alpha of 0.05 we calculated that 52 patients were required in each treatment group. Accounting for a dropout percentage of 10% a total of 58 patients was included in each group, resulting in a total sample size of 116 patients.

STATISTICAL ANALYSIS

Statistical analysis was performed with use of IBM SPSS Statistics for Macintosh, version 26.0 (Armonk, NY: IBM Corp). Baseline characteristics and outcomes (primary and secondary) are described as means with standard deviations (SD) or numbers with accompanying proportions where appropriate. Between groups differences were assessed by use of univariate Student's t-tests and chi-square tests. Primary and secondary outcomes are expressed as change from baseline (CFB) and are analyzed by use of univariate Student's t-tests as well as multivariate linear regression analyses to adjust for potential confounders (age, gender, BMI and baseline) at 3 and 12 months postoperatively. Additional linear mixed model analysis for repeated measurements (with random intercept) was performed to assess the between group difference of the NRS during the 12 months follow-up.

Between group differences are presented as means with 95% confidence intervals (CI). All analyses were performed according to the intention to treat (ITT) principle. Additionally, the proportion of patients that reached the minimal important change (MIC) for the HAGOS and NRS were calculated (pain 9.7, symptoms 10.1, ADL 11.5, sport 13.6, QoL 11.7 and NRS 1.0) and between group differences was analyzed by use of the chi-square test. [14,16]

A p-value <0.05 was considered statistically significant.

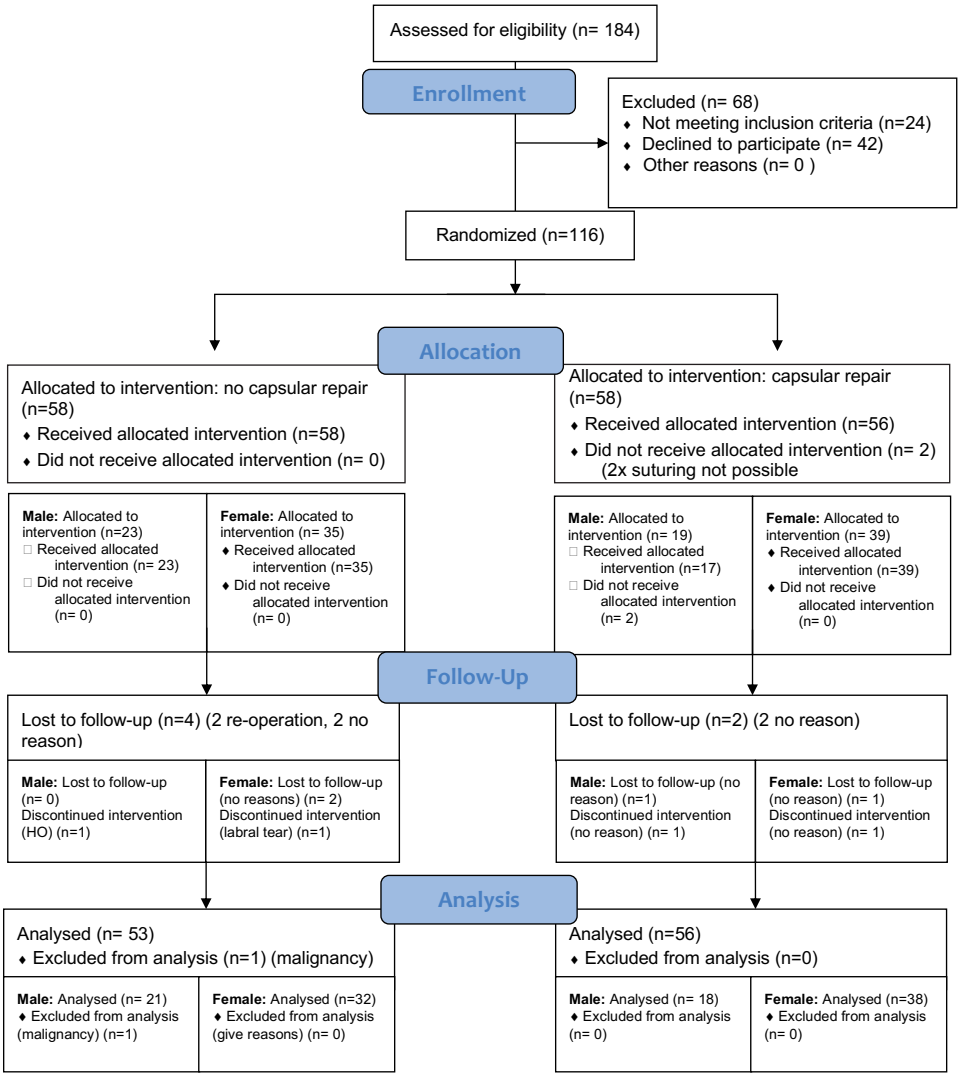

Figure 1: *CONSORT flow diagram*

RESULTS

A total of 116 patients were eligible and included in the study, 58 in both groups. In the repair group 2 patients were lost to follow-up. In the control group 1 patient was excluded 6 weeks after surgery because of a newfound malignancy, 1 patient underwent re-operation because of a labral tear, 1 patient underwent re-operation because of heterotopic ossification and 2 patients were lost to follow-up.

A total of 109 patients completed final follow-up 12 months after surgery (Figure 1). Baseline characteristics and operation details such as CAM, Pincer, labral repair or micro-fracturing were comparable between the treatment groups (Tables 1 and 2).

PRIMARY OUTCOME

The mean NRS pain scale in the control group was preoperatively 4.06 (SD 0.37) and in the repair group 4.43 (SD 0.30). In both groups the NRS was significantly decreased at 12 weeks postoperatively to values of 1.26 (SD 0.23) in the control group and 1.19 (SD 0.20) in the repair group ($p < 0.001$ for both comparisons) (Figure 2). Analysis showed no significant difference between both groups according to both crude and adjusted analysis (Table 3).

SECONDARY OUTCOME

After 12 months follow-up, both crude and adjusted analysis showed no significant difference between both treatment groups for change from baseline on NRS pain ($p = 0.53$ and $p = 0.75$, respectively). In the control group a mean decrease of 2.3 (SD 3.0) and in the repair group of 2.7 (SD 2.5) was observed (Table 3). During 12 months follow-up, the mean difference between groups was 0.02 (95% CI −0.45 to 0.48; $p = 0.95$).

The HAGOS domain scores showed similar results. Except for the sports subscale, analysis showed no significant differences between the treatment groups for all domains at both 3- and 12-months follow-up. At 3 months follow-up, a significant between-group difference was observed for the sport domain in favor of the control group ($p = 0.02$) which had disappeared at 12 months (Table 3). The MIC was reached in the control group in 68% of the patients and in the repair group 82% of the patients, no differences were found between groups regarding reaching the MIC ($p = 0.09$) (Table 3). For reaching the MIC no differences were observed between groups for all domains on the HAGOS (Table 3).

Table 1: *Baseline characteristics*

	Open (n=58)	Closed (n=58)	p-value
Gender, n (%)			
Male	23 (40%)	19 (33%)	0.44
Female	35 (60%)	39 (67%)	
Age, mean (SD)	35.5 (10.4)	33.5 (8.5)	0.25
BMI, mean (SD)	23.1 (2.7)	24.2 (2.9)	0.05
Smoking, n (%)			
Yes	3 (5%)	6 (10%)	0.49
No	55 (95%)	52 (90%)	
NRS pain, mean (SD)	4.1 (2.8)	4.4 (2.3)	0.44
HAGOS, mean (SD)			
Symptoms	47.6 (18.5)	47.6 (19.5)	0.99
Pain	50.2 (19.4)	49.1 (19.3)	0.76
ADL	54.1 (25.5)	52.7 (25.6)	0.77
Sport	39.0 (23.2)	37.2 (20.9)	0.68
QoL	33.1 (14.8)	27.9 (14.0)	0.06
CE angle, mean (SD)	34.6 (8.7)	36.0 (8.6)	0.39

Table 2: *Operation details*

	Open (n=58)	Closed (n=58)	p-value
CAM, n (%)	23 (40%)	21 (36%)	0.70
Labrum hechten, n (%)	25 (43%)	30 (52%)	0.53
Microfracturing, n (%)	5 (9%)	9 (16%)	0.25
Pincer, n (%)	36 (62%)	33 (57%)	0.57

Table 3: *the effect of closure on change from baseline (CFB) at 3 and 12 months, and proportion of patients reaching minimal important change (MIC) on the HAGOS.*

	Crude analysis			Adjusted		MIC (%)		
	Open Mean (SD)	Closed Mean (SD)	p-value	β-coefficient (95%CI)	p-value	Open	Closed	p-value
NRS pain, CFB								
3 months	-2.7 (3.0)	-3.2 (2.1)	0.30	-0.13 (-0.73; 0.47)	0.67	77%	90%	0,07
12 months	-2.3 (3.0)	-2.7 (2.5)	0.53	-0.14 (-0.98; 0.70)	0.75	68%	82%	0,09
HAGOS, CFB								
Symptoms								
3 months	21.0 (18.1)	16.5 (20.0)	0.24	-4.1 (-10.2; 2.1)	0.19	74%	65%	0,38
12 months	21.3 (20.4)	21.2 (24.1)	0.99	-0.1 (-8.8; 8.6)	0.98	73%	68%	0,64
Pain								
3 months	26.7 (18.1)	24.8 (19.0)	0.62	-3.3 (-9.4; 2.8)	0.28	84%	81%	0,70
12 months	30.8 (20.2)	30.4 (23.2)	0.94	-0.3 (-8.6; 7.9)	0.94	84%	84%	1,00
ADL								
3 months	24.5 (24.8)	21.0 (23.9)	0.48	-3.8 (-11.0; 3.4)	0.30	63%	60%	0,71
12 months	30.0 (25.8)	32.4 (26.6)	0.67	3.1 (-6.20; 12.4)	0.50	75%	71%	0,63
Sport								
3 months	25.9 (25.9)	16.8 (28.1)	0.10	-11.3 (-20.8; -1.8)	0.02	68%	54%	0,15
12 months	36.4 (26.6)	32.2 (25.1)	0.48	-3.6 (-13.8; 6.6)	0.49	77%	75%	0,80
QoL								
3 months	20.6 (18.4)	19.3 (20.8)	0.74	-4.8 (-12.2; 2.5)	0.20	66%	57%	0,34
12 months	30.6 (22.5)	34.3 (23.6)	0.45	3.6 (-6.1; 13.2)	0.46	85%	82%	0,78

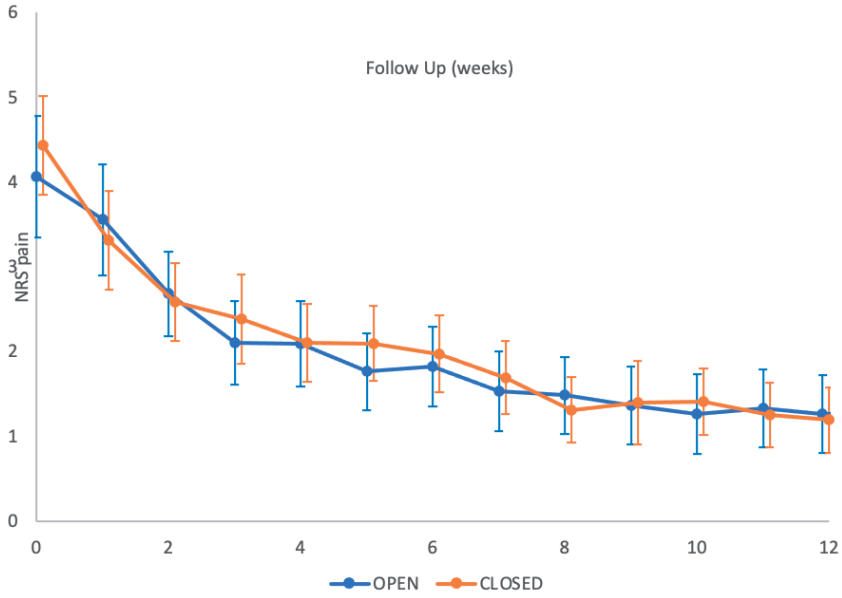

Figure 2: *postoperative NRS pain as means (SD) the first 12 weeks after surgery*

DISCUSSION

This study primarily investigated the effect of routine capsular closure after interportal capsulotomy on postoperative pain. In both treatment groups postoperative pain significantly improved after surgery but no difference was found between the groups, this is somewhat similar in current literature. A retrospective study of Domb et al. [18] showed significant improvement in both groups but no significant difference between groups at 3 months and 2 years after surgery. This is in contrast with the paper of Mygind-Klavsen et al. [19] of 2016 in which they presented the results of a matched cohort study of the Danish hip arthroscopy registry. They noticed a significant difference regarding postoperative pain measured by use of a VAS in favor of the capsular repair group at 1- and 2-years follow-up [19]. However, in a registry study a bias may be present since surgical expertise may play a role in deciding whether or not to close the capsule, since it is a challenging step of the procedure. This bias may skew the results more than the actual closure itself.

Results of our current study show that routine closure of the capsule does not have a big impact on postoperative pain as results in both groups are quite comparable. But what about the quality of the capsule after closure and the effect on postoperative outcome measures? In our study both treatment groups reported significant improvement at 3 months and 1 year after surgery and no significant difference was found between groups at final follow-up for the HAGOS score on all domains. The only significant difference

was found after 3 months in the HAGOS sport domain in favor of the unrepaired group. It is debatable how important the domain sport is 3 months after surgery. If during arthroscopy a labral or cartilage repair is performed, during the early period after surgery the patient is not allowed to fully weight bear and therefore, return to full sport activities is not even possible at 3 months. Nevertheless, there is a difference between groups and although maybe not very relevant 3 months after surgery, we believe that 1 explanation for the significant difference might be the tighter feeling of the hip because of the stitches after capsular repair. This tighter feeling might result in less degree of freedom in the hip. In the early period after surgery the stitches will more have their early strength, and this will decrease over time.

Regarding patient-reported outcome measures the results of this randomized trial are in contrast with several papers. Frank et al. [11] reported in a cohort study significant better results in the repair group on the Hip Outcome Score (HOS) for the domain sport, in the HOS-ADL and the modified Harris Hip Score (mHHS) they reported no difference between groups. The results of this paper are, however, not fully comparable with our results since Frank et al. [11] investigated the effect of complete repair versus partial repair versus unrepaired capsulotomy. The study of Domb et al. [18] reported a deterioration in the mHHS at 5 years follow-up. In this study however, there is a preoperative difference between treatment groups regarding intra-articular pathology, cartilage damage and CE angle. These differences might explain lower results regarding mHHS after 5 years and a higher conversion rate to total hip arthroplasty in the unrepaired group. [18]

In our study, the preoperative CE angle as well as other intraoperative findings were fully comparable between groups. Furthermore, follow-up in our study was only 1 year and in the study of Domb et al. [18] 5 years, therefore not fully comparable to our results.

Economopoulos et al. [12] recently investigated the effect of T-capsulotomy without closure versus interportal capsulotomy without closure versus interportal capsulotomy with complete closure in a randomized trial. They reported significant better results for the HOS-ADL in the repaired interportal capsulotomy group compared to the unrepaired interportal capsulotomy group after 2 years of follow-up, although this difference was statistically significant it was not clinically relevant. [12] Furthermore, they reported a significant difference for the mHHS after 1 year and 2 years of follow-up in favor of the repair group, again this difference was statistically significant but not clinically relevant. [12,20,21]

Regarding T capsulotomy it may be more important to repair the capsule as the cut zona orbicularis may lead to micro-instability. Economopoulos et al. [12] reports significant higher rates of conversion to total hip arthroplasty after unrepaired T-capsulotomy.

Our current study focused solely on the difference between groups after interportal capsulotomy.

The results of the retrospective paper of Atzmon et al. [22] show similar results as our current study and report no differences between both treatment groups regarding the HOS and mHHS after an average follow-up time of 3 years after surgery in patients with a normal lateral CE angle. They state that there is no reason for routine interportal capsular closure after hip arthroscopy. [22]

A recent systematic review and meta-analysis by Acuna et al. [23] evaluates most available results of capsular management after hip arthroscopy. After analysis they reported no differences between treatment groups regarding patient satisfaction, pain, range of motion and radiographic outcomes. What they did find though was a trend towards improved outcomes for capsular repair regarding patient reported outcome measures. [23] Although a trend was noticed, there are some limitations. First patient groups were not comparable between studies, there was significant heterogeneity among the available data, time to follow-up differed between studies and most studies were of level 3 or 4 evidence. The authors concluded no consensus on capsular management could be made after their meta-analysis. [23]

However, there are definitely patients who will benefit from capsular repair at the end of the procedure. There are several papers which report improved outcome after capsular plication or repair in patients with mild or borderline dysplasia. [24–26]

In patients with complaints and/or symptoms of instability and/or with a lateral CE-angle of <25° it can be beneficial to opt for capsular repair. Patients with a normal lateral CE-angle will almost never develop instability after hip arthroscopy. A review by Ilizaliturri et al. [27] mentions no report of any cases of instability caused by capsulotomy, instability only occurs after excessive bony removal from the acetabular rim. In our current study the mean preoperative CE-angle in the control group was 34.6° (SD 8.7) and in the repair group 36.0° (SD 8.6). Given the fact that results in both treatment groups were comparable and no significant difference was found we believe there is no reason for routine capsular closure in patients with a normal lateral CE-angle and no signs of instability.

To our knowledge this is the first randomized controlled trial investigating primarily the effect of routine capsular closure on postoperative pain and on the HAGOS patient reported outcome score. One of the limitations of this study is the short time of follow-up, compared to current literature a follow-up time of 1 year is quite short. Therefore, results might not yet be fully comparable.

LIMITATIONS

Our current study has some limitations; our study solely investigated the effect of routine repair after interportal capsulotomy and did not include any T-capsulotomy. Our results show no difference between groups after interportal capsulotomy but no conclusions can be made for T-capsulotomy as this type of capsulotomy was not investigated in our study. Furthermore, the follow-up is quite short, possible micro-instability might only lead, after a longer term to total hip arthroplasty. Regarding the NRS pain and the HAGOS questionnaire, there are no differences after 1year of follow-up between groups, but longer follow-up is necessary to determine if these results will hold over a longer period of time.

CONCLUSION

Results of this randomized controlled trial show no significant difference between capsular closure or unrepaired interportal capsulotomy with regard to postoperative pain and patient reported outcome up to 12 months postoperatively. In patient specific cases it is justified to choose for capsular repair, but we believe this randomized controlled trial shows highest possible evidence that there is no reason for routinely capsular closure at the end of hip arthroscopy.

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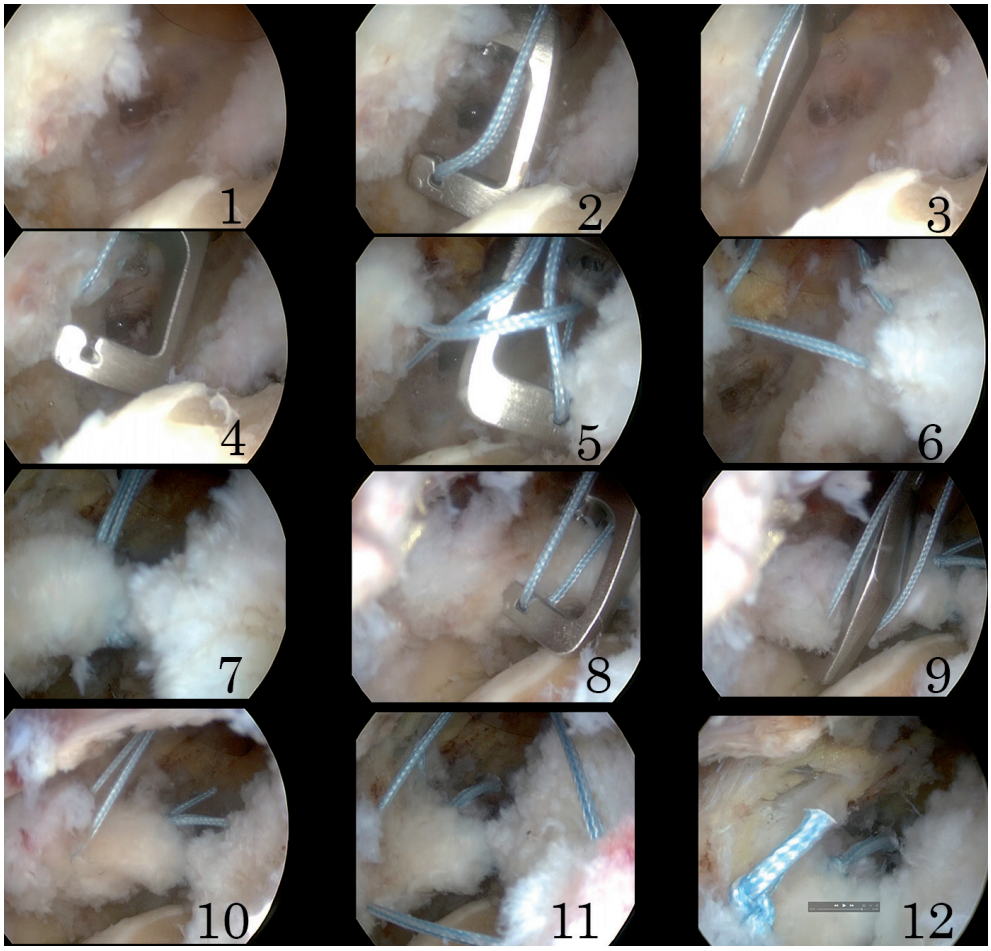

Supplementary file 1: *the hip joint capsule was completely repaired with 2 or 3 sutures by arthroscopic technique (Capsular Close Scorpion, Arthrex)*

CHAPTER 7

7

Chapter 7

INTEGRITY OF THE HIP CAPSULE MEASURED WITH MAGNETIC RESONANCE IMAGING AFTER CAPSULAR REPAIR OR UNREPAIRED CAPSULOTOMY IN HIP ARTHROSCOPY

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ABSTRACT

Background: Current literature shows no clear answer on the question how to manage the capsule after hip arthroscopy. Regarding patient reported outcome measures there seems to be no difference between capsular repair or unrepaired capsulotomy.

Aim: To evaluate and compare the integrity of the hip capsule measured on a magnetic resonance imaging (MRI) scan after capsular repair or unrepaired capsulotomy.

Methods: A case series study was performed; a random sample of patients included in a trial comparing capsular repair vs unrepaired capsulotomy had a postoperative MRI scan. The presence of a capsular defect and gap size were independently evaluated on MRI.

Results: A total of 28 patients (29 hips) were included. Patient demographics were comparable between treatment groups. There were 2 capsular defects in the capsular repair group and 7 capsular defects in the unrepaired capsulotomy group (P = 0.13). In the group of patients with a defect, median gap sizes at the acetabular side were 5.9 mm (range: 2.7-9.0) in the repaired and 8.0 mm (range: 4.5-18.0) in the unrepaired group (P = 0.462). At the muscular side gap sizes were 6.6 mm (range: 4.1-9.0) in the repaired group and 11.5 mm (range: 3.0-18.0) in the unrepaired group (P = 0.857). The calculated Odds ratio (OR) for having a capsular defect with an increasing lateral centre-edge (CE) angle was 1.12 (P = 0.06). The OR for having a capsular defect is lower in the group of patients that underwent a labral repair with an OR of 0.1 (P = 0.05).

Conclusion: There is no significant difference in capsular defects between capsular repair or unrepaired capsulotomy. Regarding clinical characteristics our case series shows that a larger CE angle increases the likelihood of a capsular defect and the presence of a labral repair decreases the likelihood of a capsular defect.

INTRODUCTION

Hip arthroscopy is a more and more popular technique to address intra-articular pathology of the hip [1,2]. Entrance to the hip is made by several portals and usually an interportal or T-shaped capsulotomy is performed to improve workspace in the joint [3]. In the early days of hip arthroscopy these capsulotomies were usually left unrepaired [4]. In recent years there has been debate on what to do with the capsulotomy at the end of the procedure. Some papers suggest that routine capsular closure might result in improved outcomes after surgery where other papers report conflicting evidence and show no superiority of routine capsular repair [5-10]. However, there are cadaveric studies that show the biomechanical importance of complete capsular repair [11,12]. Restoration of the hip joint capsule results in hip joint kinematics to near normal levels after interportal or T-shaped capsulotomy [12].

The unrepaired hip capsulotomy might be a reason for developing postoperative iatrogenic hip instability [13,14]. As the (un)repaired capsulotomy might be a contributor to postoperative complaints of patients with iatrogenic hip instability, this may be quantified by assessment of the quality and morphologic appearance of the hip capsule with magnetic resonance imaging (MRI) [15].

The purpose of this study is to evaluate the integrity of the hip capsule after capsular repair or unrepaired capsulotomy measured with MRI. Our secondary aim is to evaluate the association between pre- and perioperative details and the quality and integrity of the capsule.

MATERIALS AND METHODS

STUDY DESIGN AND PARTICIPANTS

For the current study a random sample of 28 patients (29 hips) with residual hip complaints after surgery or complaints of the contralateral hip had an MRI scan postoperatively and were enrolled in the current study. All patients were part of a trial that was designed and approved after local medical ethical committee approval (NL55669.048.15).

Inclusion criteria for the trial were age between 18-65 years, a body mass index (BMI) lower than 35 and good understanding of Dutch/English language and with intra-articular hip pathology who opt for hip arthroscopy. Exclusion criteria were revision hip arthroscopy, extra-articular hip pathology, a documented systemic connective tissue disease or hypermobility, a centre-edge (CE) angle of less than 25 degrees, prior hip surgery or a hip fracture in the past. After randomization patients were either allocated to repaired

capsulotomy or the unrepaired capsulotomy group. All patients were operated by the senior author. Functional outcome was measured at baseline and after 12 mo follow-up with the Copenhagen Hip and Groin Outcome Score (HAGOS) [16].

The postoperative MRI scans were independently evaluated for capsular integrity by Bech NH and Haverkamp D to assess inter observer reliability. Both authors were blinded to clinical and detailed operative information to prevent bias.

Final cohort consisted of 29 hips (28 patients) of which 16 were in the unrepaired group and 13 in the capsular repair (repair) group that had received a postoperative MRI scan.

SURGICAL TECHNIQUE

Patients were operated via standard technique and 2 or 3 portals were made. An interportal capsulotomy was done in all patients. No T-shaped capsulotomies were done. Repair of the capsule took approximately 15 min of operating time. The capsular repair was done with 2 or 3 sutures by arthroscopic technique (Capsular Close Scorpion, Arthrex). Standard sutures were used (Fibrewire, Arthrex).

POSTOPERATIVE PROTOCOL

In both groups the rehabilitation protocol was similar. The first 4 wk no weight bearing was allowed. After that, patients started weight bearing with crutches. From week 5 till week 12 patients started with passive and active exercises and were guided by a physiotherapy. After week 12 there were no more restrictions. All patients received standard 4 wk of non-steroid anti-inflammatory drugs (diclofenac) to inhibit heterotopic ossification.

CAPSULAR QUALITY ASSESSMENT ON MRI

The used technique for measuring capsular defects has been previously described in the paper of Strickland et al [17]. Capsular integrity was measured on a proton weighted density sequence or the T2 weighted fat-saturated sequence in the coronal plane. First step was to determine if there was a capsular defect (Figure 1). The definition of a capsular defect was described by Weber et al [18]; being any visual disruption of the iliofemoral ligament or any appearance of communication between the joint and the iliofemoral bursa seen with contrast (Figure 1A and B) [18]. Furthermore, we measured 2 parameters: Gap length on the acetabular side and the gap length on the muscular side of the defect (Figure 1A and B).

STATISTICAL ANALYSIS

Patient and clinical characteristics are described as means ± SD in case of normally distributed continuous variables. Otherwise, medians with ranges are presented. Comparisons between repair groups were performed by use of t-tests or non-parametric

Mann Whitney U-tests where appropriate. Categorical variables are presented as numbers with accompanying proportions and analyzed by use of $\chi 2$ tests or Fischer Exact-tests (in case of expected numbers < 5). For the presence of a capsular gap, absolute agreement was calculated to present inter observer reliability. The association between pre and perioperative details and the presence of a defect was analyzed by use of a univariate logistic regression analysis and Odds ratios (OR) with 95%CI were calculated. Intra class correlation coefficients (ICC-agreement, 2-way random effect model) were calculated for both acetabular and muscular gap length. A P value < 0.05 was considered statistically significant.

Analysis was performed by use of SPSS statistical software (IBM Corp. IBM SPSS Statistics for Macintosh Version 26.0. Armonk, NY: IBM Corp).

RESULTS

PATIENT DEMOGRAPHICS

The mean age in the unrepaired group was 33.3 ± 6.1 and in the repair group 31.4 ± 9.1. Average follow up in the repair group was 15.8 ± 6.5 mo and in the unrepaired group 12.6 ± 6.7 mo. Regarding baseline characteristics there were no significant differences between both groups (Table 1).

Regarding the HAGOS functional outcome score both baseline and 12 mo follow-up values are given in Table 2. In the capsule defect group, 7 patients reached the 12 mo follow-up, in the capsule intact group, 16 patients reached the 12 mo follow-up. Between the capsule intact and the capsular defect group, there were no differences on all 5 domains of the HAGOS outcome score (Table 2).

CAPSULAR DEFECTS

In total there were 9 capsular defects measured on MRI, 20 hips did not have a capsular defect. For the assessment of the presence of capsular defect there was 100% agreement between observers. In the repair group, there were 2 patients (15.4%) with a measurable capsular defect on MRI, and in the unrepaired group 7 patients (43.8%) (P = 0.13).

In the capsular repair group, there were 2 failures. The first was a 23-year-old woman with a large CE angle (44 degrees) and a BMI of 24,6. The second patient was a 45-year-old woman with a hip that had already some signs of osteoarthritis, a CE angle of 36.9 degrees and a BMI of 33.3.

GAP SIZE

Inter observer reliability of gap size measurements was good to excellent with ICC values of 0.83 and 0.94 of the gap measurements at the acetabular and muscular side.

Among patients with a capsular defect, median gap sizes at the acetabular side were 5.9 mm (range: 2.7-9.0) and 8.0 mm (range: 4.5-18.0) in the repaired and unrepaired group, respectively (P = 0.462). At the muscular side, gap sizes were 6.6 mm (range: 4.1-9.0) and 11.5 mm (range: 3.0-18.0), respectively (P = 0.857).

CLINICAL CHARACTERISTICS AND CAPSULAR DEFECT

Although not significant patients with a larger CE angle were more likely to have a capsular defect on MRI with an OR of 1.12 (P = 0.06). In the group of patients with a capsular defect, there were 2 with a CAM-type deformity and 5 with a pincer-type deformity. In the capsule intact group, there were 6 patients with a CAM-type deformity and 9 patients with a pincer-type deformity. There was no significant association between the presence of a CAM or pincer deformity and a capsular defect (Table 3).

In the capsular defect group, there was 1 patient that underwent a labral repair; in the capsule intact group, 11 patients underwent a labral repair. Patients with a labral repair were less likely to have a capsular defect on MRI with an OR of 0.1 compared to patients without labral repair (P = 0.05) (Table 3).

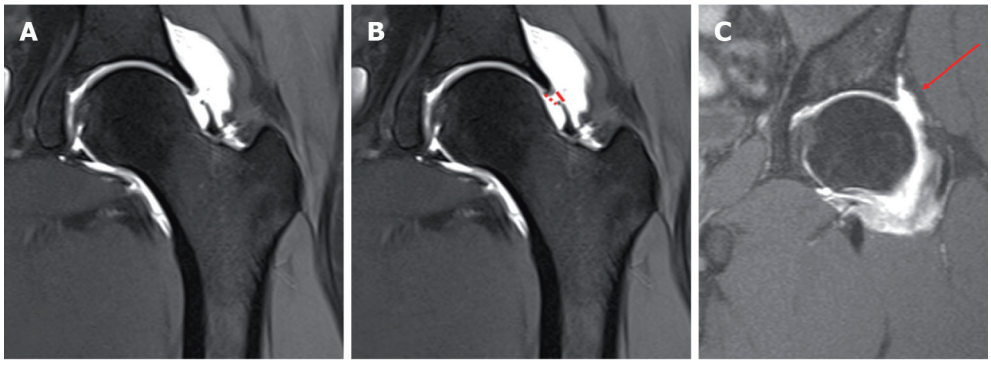

Figure 1: *Example of capsular defect and intact capsule on magnetic resonance imaging-arthrography.*

A: example of a capsular defect on magnetic resonance imaging (MRI)-arthrography with extracapsular contrast leakage to the adjacent soft-tissue; B: Gap length measurement; solid line: gap length muscular side. Dotted line: Gap length acetabular side; C: Example of an intact capsule on MRI-arthrography (Arrow). There is no contrast leakage to the adjacent soft-tissue.

Table 1: *Patient demographics. Data are presented as n (%) or mean ± SD. BMI: Body mass index; CE: Centre-edge; MRI: magnetic resonance imaging.*

	Repaired (n=13)	**Unrepaired** (n=16)	**P-value**
Sex, n (%)			0.36
Male	4 (30.8%)	2 (12.5%)	
Female	9 (69,2%)	14 (87.5%)	
BMI, mean (SD)	23.8 (3.9)	23.1 (2.3)	0.67
Age, mean (SD)	31.4 (9.1)	33.3 (6.1)	0.49
Follow-up (months), mean (SD)	15.8 (6.5)	12.6 (6.7)	0.72
Impingement type			
CAM (n, %)	5 (38.5%)	3 (18.8%)	0.62
Pincer (n, %)	5 (38.5%)	9 (56.3%)	0.34
Labral repair (n, %)	5 (38.5%)	7 (43.8%)	0.22
CE angle at time of MRI (degrees), mean (SD)	38.2 (7.7)	34.0 (9.8)	0.48

Table 2: *Hip and Groin Outcome Score functional outcome score at baseline and after 12 mo follow-up HAGOS: Hip and Groin Outcome Score; IQR: Interquartile Range; FU: Follow-up; ADL: Activity of daily living; QoL: Quality of life.*

Baseline	**Capsular intact** (n=20)	**Capsular defect** (n=9)	**p-value**
HAGOS, median (IQR)			
Symptoms	44.6 (35.7; 58.9)	35.7 (28.6; 37.5)	0.08
Pain	43.8 (32.5; 54.4)	35.0 (31.3; 48.8)	0.39
ADL	47.5 (26.3; 65.0)	40.0 (40.0; 67.5)	0.84
Sport	32.8 (19.5; 43.0)	25.0 (19.5; 37.5)	0.71
QoL	25.0 (15.0; 35.0)	25.0 (21.3; 38.8)	0.64
12 months FU	**Capsular intact** (n=16)	**Capsular defect** (n=7)	**p-value**
HAGOS, median (IQR)			
Symptoms	51.8 (32.1; 74.1)	39.3 (35.7; 64.3)	0.82
Pain	70.0 (48.8; 86.3)	60.0 (40.0; 92.5)	0.87
ADL	67.5 (40.0; 90.0)	60.0 (50.0; 95.0)	0.62
Sport	53.6 (25.8; 80.5)	53.1 (35.7; 81.3)	0.87
QoL	40.0 (26.3; 53.8)	60.0 (40.0; 60.0)	0.28

DISCUSSION

In this case series we found that the incidence of a capsular defect, although not significant, was higher in the unrepaired capsulotomy group than in the repaired group. Our results are comparable to available current literature. In the randomized controlled trial of Strickland et al [17] they investigated 30 hips and compared capsular closure vs unrepaired interportal capsulotomy during simultaneous bilateral arthroscopy. They measured the capsular defect and the quality of the capsule postoperatively and report no significant differences between treatment groups at final endpoint at 24 wk after surgery.

Kraeutler et al [19] performed a multicenter randomized trial between capsular repair and unrepaired capsulotomy. They also report no differences between both treatment groups regarding healing of the capsule measured on MRI [19].

In the paper of Weber et al [18] symptomatic patients were evaluated with MRI after capsular repair. They reported that 1 year after surgery 92.5% of the repaired capsules remained closed and that the capsule was thickened at the site of the repaired capsulotomy compared to the unaffected contralateral hip capsule [18].

To our best knowledge there is no literature that investigated the association between the size of the CE-angle and the presence of a capsular defect. In our series the likelihood of a capsular defect was larger with an increasing CE angle. An explanation for this finding could be that in this group the incidence of pincer impingement was higher. As part of the procedure of pincer impingement the surgeon must resect a part of the acetabulum and detach a part of the iliofemoral ligament. Extended resection and concomitant ligament damage could lead to possible higher incidence of capsular defects after surgery.

In our series there were only 2 failures in the capsular repair group that showed a capsular defect on MRI. Possibly the rather large CE angle in both patients was of influence and led to subsequent failure of capsular healing. Regarding labral repair there was a significant larger portion of patients with an intact capsule in the labral repair group. It is unsure where the difference in capsular defects between labral repair and no repair originates from. A possibility is that more stability from a repaired labrum influences the capsular healing. Cadaveric studies show that an intact labrum absorbs a lot of strain during motion of the hip [20]. Without the intact labrum the hip capsule might have to compensate for these forces resulting in possibly a higher incidence of capsular defects.

STRENGTHS

A strength of this study is that the capsular defect was measured by two authors separately and that an intra classifier coefficient was calculated to verify the accuracy of the measured defects.

LIMITATIONS

The first limitation of this study is that small number of patients were included. We expect that although there was a clinically relevant difference in measurable defect between the groups, this difference was not statistically different because of the small sample size. Secondly, only symptomatic patients or patients with complaints of the contralateral hip had an MRI scan and this could have introduced a bias in our results.

Table 3: *Association between clinical characteristics and presence of a capsular defect. CE: Centre-edge; MRI: magnetic resonance imaging.*

	OR (95%CI)	P-value
CE angle at time of MRI	1.12 (1.00; 1.26)	0.06
CAM	0.67 (0.11; 4.20)	0.67
Pincer	1.53 (0.31; 7.44)	0.60
Labral repair	0.10 (0.01; 0.98)	0.05

CONCLUSION

Our current study shows that there is no significant difference in capsular healing on MRI between capsular repair or unrepaired capsulotomy. Furthermore, a higher CE angle increases the likelihood of having a capsular defect and the presence of a labral repair decreases the likelihood of a capsular defect. Although there seems to be no reason for routinely capsular closure after hip arthroscopy, knowing these patient specific factors might help the orthopedic surgeon to decide to perform a capsular repair in specific cases.

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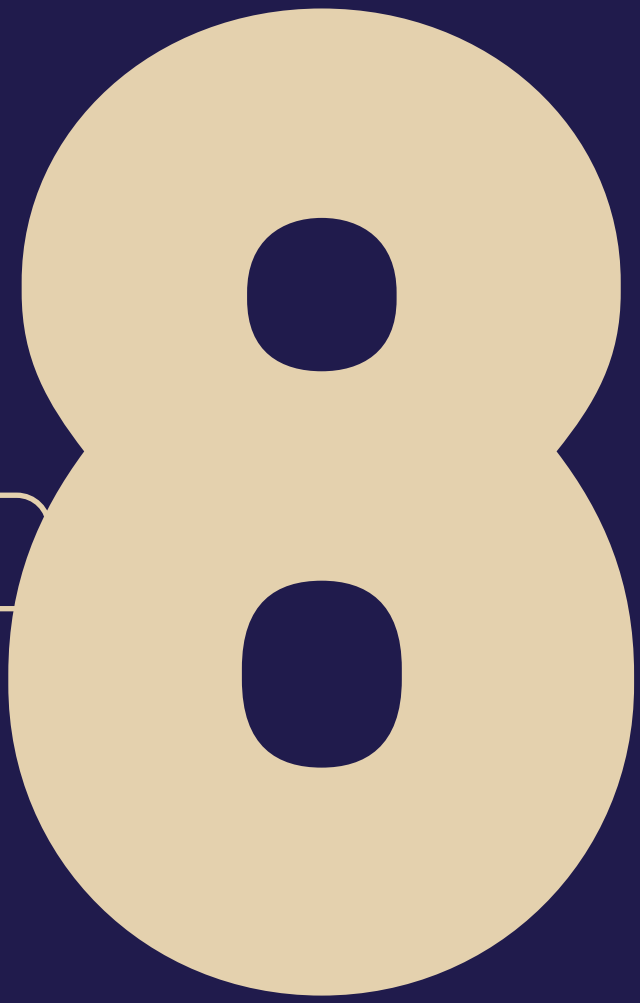
CHAPTER 8



Chapter 8

GENERAL DISCUSSION

PATIENT SELECTION

From 2000 to 2014, the number of hip arthroscopies performed showed a consistent upward trend. However, starting in 2015, there was a decrease in the figures reported in national registry studies (figure 1) [1]. The most recent updated report of the Danish Hip Arthroscopy Registry (DHAR) confirmed this trend with 837 procedures performed in 2020 declining to a number of 724 hip arthroscopies in 2022 [1].

This decline could be ascribed to the increased understanding of patient selection, the accumulation of more evidence, and an increased level of experience with the procedure. The first part of this thesis aims to identify factors that might be predictors of poor outcome after hip arthroscopy.

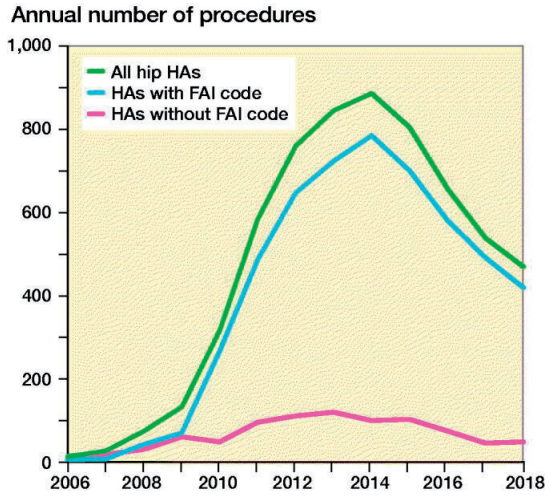


Figure 5: *number of hip arthroscopies performed in Sweden between 2006 and 2018, FAI = femoroacetabular impingement (reprint with permission [1])*

There are several patient characteristics that might influence the outcome of hip arthroscopy. But before we continue to discuss these patient characteristics it is important to realize that hip arthroscopy is an umbrella term to describe a part of the surgical procedure and should not be confused with the different procedures itself nor with the specific pathologies treated by these procedures. For example, a patient with a degenerative labral tear and a Kellgren-Lawrence grade 1 osteoarthritis has probably a different outcome than the young athletic patient with solely a cam lesion.

DEMOGRAPHIC PREDICTORS

There are several demographic factors such as age, gender and BMI that influence the outcome after hip arthroscopy. In a large database study of Rogers et al they show that increasing age (threshold of >60 years) is significantly correlated with poor outcome after hip arthroscopy [2]. In this study a poor outcome was defined as the need for revision arthroscopy or conversion to total hip arthroplasty (THA) within the first year after primary surgery. In Lin et al.'s cohort study, subjects were categorized into three age groups (15-34, 35-50, and 51-75). The study revealed that individuals in the older age group exhibited notable improvement from baseline but also experienced a significantly heightened risk of transitioning to total hip arthroplasty (THA) [3]. The population-based database study of Schairer et al confirms these findings and shows there are several factors that predict poor outcome after hip arthroscopy [4]. In this database study patients with an increasing age (threshold >40 years), the presence of osteoarthritis and patients with obesity were more likely to proceed to total hip arthroplasty within 2 years after primary hip arthroscopy [4].

Chapter 2 discusses the results of our review and meta-analysis of hip arthroscopy in obese patients. Our analysis shows that obesity is a significant risk factor for hip arthroscopy patients to undergo THA or the need for revision hip arthroscopy. In our analysis obesity doesn't lead to an increased number of complications after hip arthroscopy. Regarding functional outcome our analysis shows that obese patients improve equally to non-obese patients but score significantly lower on overall outcome than non-obese patients. One disadvantage of our review is that it was already published in 2015 and at the moment of writing only 2 papers were suitable for inclusion in our analysis. It is interesting to compare our data with more recent literature. Kuroda et al published a systematic review in 2021 and performed a meta-analysis of 8 studies (including the 2 studies we included in our paper in 2015)[5]. They report that conversion to THA and complication rates were higher in the obese group. Furthermore, their analysis shows that obese patients present significantly lower patient reported outcome scores than non-obese. The conclusion of our paper and recent literature is that it is fair to state that obesity is a relative contra-indication and a possible predictor for poor outcome after hip arthroscopy.

HIP PATHOLOGY AND MORPHOLOGY

It is important to realize that different hip pathology and hip joint morphology might lead to different outcomes after hip arthroscopy. A recent review by Kyin et al shows that the presence of osteoarthritis is a predictor of early conversion to THA and poor patient reported outcomes after 5-10 years of follow-up [6]. However, in a comparative cohort analysis conducted by Sivasundaram et al., it was demonstrated that individuals displaying

early signs of osteoarthritis (Tonnis grade 1) exhibited significant enhancements in the Hip Outcome Score and Harris Hip Score five years post-surgery [7]. Although patients with Tonnis grade 1 displayed lower postoperative outcome scores in comparison to those without osteoarthritis, there was a significant improvement from the baseline following hip arthroscopy for femoroacetabular impingement (FAIS).

Similar findings were observed in the randomized trial conducted by Martin et al. In this trial, patients aged over 40 with a labral tear and Tonnis grade 0-2 osteoarthritis were randomized into two groups: physiotherapy alone or hip arthroscopy followed by postoperative physiotherapy. The arthroscopy group reported superior outcome scores compared to the physiotherapy-alone group [8]. The outcomes of these two studies suggest that the decision to undergo surgery in the presence of osteoarthritis is highly patient-specific. For a 35-year-old patient with Tonnis grade 1, opting for surgery may be a prudent choice, potentially delaying the progression to advanced osteoarthritis by 5 or 10 years.

The severity of osteoarthritis is associated with a higher risk of rapid progression to THA [9]. A known risk factor to develop early osteoarthritis of the hip is Femoroacetabular Impingement Syndrome (FAIS) [10]. FAIS is one of the main indications for hip arthroscopy, a recent paper by Menge et al shows excellent long-term results after 10 years in a group of patients that underwent hip arthroscopy for FAIS combined with a labral repair [11]. More long-term series back this up, however we have to consider that good long-term follow-up series of conservative treatment of FAIS are lacking.

Besides FAIS there are also patients with a different type of hip impingement that are possibly suitable for hip arthroscopy. **Chapter 3** describes three lesser-known types of hip impingement. We explain the concept and provide relevant information regarding clinical information, diagnostic tests and possible treatment options of anterior inferior iliac spine (AIIS) impingement (also known as subspine impingement (SSI)), ischio-femoral impingement (IFI) and pelvitrochanteric impingement.

For patients with AIIS impingement it seems that arthroscopy of the hip might be a good solution in which both intra-articular pathology as well as the extra-articular AIIS impingement can be addressed. A more recent study of Borrego et al shows similar satisfying results of 10 patients that underwent trimming of the excessive AIIS arthroscopically [12]. According to our results and current literature it can be said that hip arthroscopy is a safe and satisfying procedure for patients with AIIS impingement.

There are several treatment options for IFI, conservative treatment, open osteoplasty of the lesser trochanter or endoscopically release of the quadratus muscle and osteoplasty

of the lesser trochanter. In our review we describe the satisfying results in 2 case series of patients that are endoscopically treated for IFI. Since our review there are only 2 more case series that report the outcome of endoscopically treated patients with IFI [13,14]. Both case reports show satisfying results and pain relief after endoscopically osteoplasty of the lesser trochanter. IFI is quite rare but it is important to recognize the symptoms and refer if necessary to a hip arthroscopy surgeon for possible endoscopically release of the ischiofemoral space.

Pelvitrochanteric impingement is usually seen in patients with a history of Legg-Calve-Perthes disease, slipped capital femoral epiphysiolysis or septic arthritis. The deformity with a shortened femoral neck and a more prominent greater trochanter causes impingement during abduction of the hip. Furthermore, the shortened distance between the ilium and greater trochanter can induce a Trendelenburg gait. Treatment options are conservative treatment or open osteotomy of the femur. Patients with pelvitrochanteric impingement are not suitable for hip arthroscopy or at least no options are described yet.

PATIENT SPECIFIC FACTORS

The most frequently reported risk factor for a negative outcome after hip arthroscopy is older age and female gender [15]. Also an increased BMI and already present osteoarthritis of the hip are important predictors of a negative outcome [15]. Other lesser known risk factors for a poor outcome are more patient specific and include mental health and psychological state [16,17].

In **Chapter 4** the role of pain catastrophizing and central sensitization on the reported pain after hip arthroscopy is described. The results of our study show that both the pain catastrophizing scale (PCS) and the central sensitization index (CSI) are associated with the reported pain after hip arthroscopy. The group of patients with a CSI score higher than 40 (indicating possible central sensitization (CS)) the reported NRS pain was on average 1.47 points higher than the non-CS group. This difference was clinically relevant and statistically significant. There is no literature debating the role of CS in hip arthroscopy but there are some papers that discuss the role of CS in knee arthroplasty surgery. A recent systematic review and meta-analysis of Kim et al reports on the pooled data of 5 studies that evaluated pain scores after total knee arthroplasty (TKA) and the role of CS [18]. In their review they show that pre-operative CS is related to a poor clinical outcome after surgery in patients who underwent TKA with a diagnosis of knee osteoarthritis. They performed a meta-analysis and showed that the group of patients with CS experienced more severe and persistent pain after surgery than the non CS group [18]. There are several reasons why CS patients report more and severe pain after surgery and are more likely to

show inferior outcome after surgery. CS patients tend to have too high expectations after surgery in terms of pain relief and well being and CS patient also have a higher sensitivity to pain [19,20]. The results in **Chapter 4** show parallels with the paper of Kim et al as the CS patients in our study reported significantly higher on the NRS pain score (1.47 points). Unfortunately, the sample size was small and only 12 patients (out of 37) scored >40 points on the CSI, indicating possible CS.

Regarding the pain catastrophizing scale (PCS) the results in **Chapter 4** show that the PCS is associated with the reported NRS pain after surgery. In a recent study of Clapp et al they show that the reported PCS scores 1 year after surgery were significantly lower in the group of patients achieving the minimum clinically important difference (MCID) than patients that did not [21]. In their study there was no correlation of the pre-operative PCS score and the ability of reaching the MCID.

Although often used for similar purposes it is important to distinguish between the MCID and the minimal important change (MIC). To prevent confusion arising from the similarity of these terms, it is crucial to focus on the 'change' in Minimally Important Change (MIC) and the 'difference' in Minimal Clinically Important Difference (MCID). The MIC signifies the slightest alteration in a Patient-Reported Outcome Measure (PROM) score (compared to baseline) that a patient acknowledges as a clinically significant change [22]. For instance, if a patient's change score falls below the MIC, their clinical outcome is not noticeably different from the baseline, as perceived by the patient. The MIC should be employed when evaluating changes within a cohort (e.g., preoperative to postoperative). In contrast, when examining distinctions between groups (e.g., study group with implant A vs. control group with implant B), the MCID of a PROM should be utilized to interpret results. The MCID represents the smallest difference between two measurements that is deemed important by patients. The study of Clapp et al. states that the PCS can be used as a tool in the postoperative phase to identify patients that are possible at risk for not reaching the MCID and a poor outcome after hip arthroscopy [21].

In hip arthroscopy both the PCS and CSI can serve as tools as predictors of persistent pain and poor outcome after surgery. This doesn't mean that pain catastrophizing and central sensitization are contra-indications for hip arthroscopy but it's important to realize that sometimes these patients will benefit from a more personalized approach. This individualized approach may involve comprehensive preoperative counseling and thorough discussion of patients' expectations.

OPTIMISING OUTCOME

In order to enhance patient satisfaction and achieve favorable outcomes following hip arthroscopy, it is crucial to distinguish between long-term results and immediate postoperative pain. Long-term outcomes in hip arthroscopy are typically assessed through functional outcome scores and/or the occurrence of secondary surgeries, such as total hip arthroplasty or revision arthroscopy.

Early postoperative pain significantly impacts a patient's ability to mobilize promptly, affects opioid consumption, and plays a pivotal role in overall patient satisfaction. Consequently, it is essential to optimise perioperative pain management, particularly in the immediate post-surgery period.

PERIOPERATIVE PAIN MANAGEMENT

Regarding peri- and postoperative pain management in hip arthroscopy there are several options described in **Chapter 5**. These options can be divided in 3 groups; oral pain medication, local anesthesia (being portal infiltration or joint infiltration directly after arthroscopy) and the third option is a peripheral nerve block; femoral nerve block, fascia iliaca block or even lumbar plexus block.

An international survey among 215 hip arthroscopy surgeons in 2020 concluded there was a lack of clinical agreement in perioperative pain management in hip arthroscopy [23]. The use of oral NSAIDS postoperatively was the only clinical treatment that reached agreement in 80%. In our review there is only 1 paper that describes the effect of oral pain medication (NSAID) and shows that the use of this NSAID results in less pain and less pain medication usage after surgery. A potential beneficial side effect of NSAID usage is the prevention of heterotopic ossification after hip surgery [24].

Regarding local anesthesia there seems to be no difference between portal infiltration and intra-articular infiltration regarding pain scores early after surgery. This might be attributed to the fact that the hip capsule is left unrepaired at the end of the procedure, allowing intra-articular anesthesia to disperse into the surrounding tissues and replicate the effects of portal infiltration.

Regarding peripheral nerve blocks the femoral nerve block seems to be the most promising option. One main shortcoming is the large heterogeneity between studies; different outcomes were measured, different patient groups were included, different dosages and techniques were used for the nerve blocks. Therefore, it was not possible to

pool the data and perform a meta-analysis. The search for our review was performed in 2015 and it is interesting to see if there are nowadays more recent publications or papers on the matter. In a systematic review of Kunze et al (2020) they included the results of 14 randomized controlled trials published since 2007 (9 since our review was published in 2016). The conclusion of their systematic review was that adjunct analgesia (being a peripheral nerve block, periportal local anesthesia or oral medication was effective in providing pain relief after surgery [25]. They did perform a meta-analysis and although there was a large heterogeneity between studies their results show that the use of local infiltration analgesia seems to provide the greatest benefit in terms of pain relief and reduction of opioid usage after surgery [25].

A more recent study by Kim et al evaluated the effect of a peripheral nerve block compared to local anesthesia [26]. Their meta-analysis of 8 included studies shows no benefit of a peripheral nerve block compared to local anesthesia alone regarding postoperative opioid consumption and pain control [26]. The results in **Chapter 5** mainly describes the effect of adding a peripheral nerve block compared to general anesthesia alone. Although some studies discussed in **Chapter 5** show promising results no hard evidence was found and no clear recommendations could be made regarding the use of a peripheral nerve block. Combined with the results of the recent meta-analysis of Kim et al it can be said that adding a peripheral nerve block seems to have no benefit in pain relief compared to general anesthesia with local infiltration anesthesia.

In **Chapter** 5 there is only 1 paper (Zhang et al) that evaluates the effect of oral pain medication (being a COX-2 inhibitor) and shows that the use of a COX 2 inhibitor results in less pain and less pain medication usage after surgery. Kunze et al included 2 more studies that evaluated the effect of oral celecoxib and concludes that (pre-operative) celecoxib results in lower postoperative pain scores and shorter time until PACU discharge [25].

In recent years the relative new Pericapsular Nerve Group (PENG) block was introduced and seemed to show promising results in hip surgery [27]. This PENG block was also introduced in hip arthroscopy and the results of a recent published RCT of Eppel et al show that patients that received the PENG block experienced less postoperative pain between the 18th and 24th hour after surgery [28]. However, regarding opioid consumption there was no difference between the PENG block group and the control group [28].

The randomized controlled trial by Amato et al. shows no significant differences in postoperative pain and opioid consumption between patients who underwent a PENG block and the control group, which received a sham block [29]. In contrast, the retrospective cohort study by Yusupov et al. presents encouraging findings regarding the PENG block. They observe improved perioperative outcomes characterized by reduced

opioid consumption, diminished pain, shorter time to discharge, and decreased use of antiemetics after surgery [30]. While it is challenging to assert that the PENG block is the ultimate solution for perioperative pain control, it undeniably has potential and may assume a crucial role in future research.

Chapter 5 gives a good overview of possible therapeutic options to minimize pain after hip arthroscopy. A potential strategy for achieving optimal perioperative pain management involves the use of an oral COX-2 inhibitor in combination with local/portal infiltration. If this proves insufficient postoperatively, the option to administer an additional nerve block can be considered, aiming to minimize opioid usage and optimise postoperative pain control. The choice of nerve block is under influence of local protocol and preference of the anesthesiologist. Or to cite Timothy Jackson who wrote an editorial on the matter recently: "the optimal nerve block for hip arthroscopy is undetermined and a patient tailored approach is indicated" [31].

CAPSULAR MANAGEMENT

A returning topic of debate last years is the management of the capsule at the end of hip arthroscopy [32–34]. **Chapter 6** tries to give a partial answer on the question what the best option is regarding capsular management. In the randomized controlled trial patients were divided into 2 groups, one group in which the capsule was repaired and the other group in which the capsule was left unrepaired. Outcome was measured with the NRS pain score and the HAGOS patient reported outcome. The most important finding of the CLOSE trial is that after 12 months follow-up there was no difference between groups regarding the reported NRS pain as well as for the reported HAGOS outcome score. Although the results of the CLOSE trial seem to be quite clear there are some points of discussion. The duration of follow-up (12 months) is shorter compared to other papers that report on the matter and we have to see if the results will hold the next coming years. This holds significance as the unrepaired capsule could potentially result in capsular instability over the long term, increasing the risk of labral tears and cartilage damage. Ultimately, this may contribute to compromised hip function and a potential need for early conversion to total hip arthroplasty.

One other shortcoming is that in the CLOSE trial only repair after interportal capsulotomy is measured. In some patients it is necessary to perform a T-shaped capsulotomy, in these cases a more extended capsulotomy is done to work inside the hip joint. Regarding the T-shaped capsulotomy it maybe is more important to repair the capsule compared the interportal capsulotomy group. This is due to the cut zona orbicularis that may lead to micro-instability later in life. The concept of hip micro-instability, a relatively recent

diagnosis, has seen a growing acknowledgment in both clinical practice and literature in the past decade. Micro-instability is typically characterized by the persistent presence of excessive hip motion, insufficient to be categorized as dislocation or subluxation, but significant enough to cause symptoms, particularly pain. The findings of an international consensus study on hip micro-instability were published in 2023. The study indicates that an unrepaired hip capsulotomy is a minor contributing factor in diagnosing hip micro-instability [35]. Consequently, it becomes crucial to assess whether the encouraging outcomes of the CLOSE trial will be sustained over the long term.

Within 8 months after publication of the results of the CLOSE trial two separate systematic reviews were published on the subject [36,37]. The first by Kunze et al was published in June 2021, they performed a systematic review and included 6 papers for their meta-analysis and focused mainly on the possibility of patients achieving the Minimal Clinical Important Difference (MCID) [36]. They report that capsular closure has no influence on the rate of achieving the MCID for the HOS-ADL (Hip Outcome Score Activities of Daily Living) and the HOS-SS (Sports-Subscale). What they did find was that capsular repair led to a significant higher rate of patients achieving the MCID for the modified Harris Hip Score (mHHS). It is debatable whether this is relevant as the mHHS consists of only 8 questions and was originally not designed as a score for hip preservation surgery. The HOS-ADL and HOS-SS are possibly more important and reliable in hip preservation surgery [38]. An other important limitation of this study is the inclusion of both interportal and T-shaped capsulotomies in the analysis, without conducting a subgroup analysis to compare the specific outcomes of interportal versus T-shaped capsulotomy [36].

The other review by Owens et al was published in September 2021, they included a total of 16 studies for their analysis [37]. They state that capsular repair is a safe procedure and may result in superior patient-reported outcomes compared to unrepaired capsulotomy. There are some limitations in this review though; a large heterogenous group of patients was included. The size of capsulotomy between patients differed being a T-shaped capsulotomy, interportal capsulotomy or an extended capsulotomy [37]. The type of repair also differed and was a complete repair, partial repair or an unrepaired capsulotomy. Furthermore, the technique of the capsular repair varied between studies; a simple single stitch or a figure of 8 repair [37]. Two reviews in the same time period with a different conclusion is an indication of poor evidence combined with possible investigator bias.

The results of the CLOSE trial in **Chapter** 6 show high evidence that after a routine interportal capsulotomy there is no reason for standard capsular repair. For the orthopedic surgeon it still is important to realize that patient specific reasons or aberrant anatomy might still be a reason to perform a capsular repair.

Regarding clinical and functional outcome, it seems that capsular repair after interportal capsulotomy doesn't have a significant influence after 1 year of follow-up. But what about actual healing of the capsule, does the capsular repair has its effect on capsular healing or does an unrepaired capsulotomy also leads to possible capsular healing?

In the study described in **Chapter 7** the integrity of the hip capsule was measured on an MRI scan in 28 patients (29 hips) after arthroscopy. There were 13 patients in the capsular repair group of which 2 had a capsular defect on the MRI scan, in the unrepaired capsulotomy group there were 16 patients of which 7 had a capsular defect on MRI. This difference was not significant (p=0.13) but the number of included patients was very low and no power analysis was performed.

After additional analysis of clinical characteristics, it was found that patients with a larger preoperative CE angle were more likely to have a capsular defect on MRI (OR of 1.12). On the contrary; it seems that the presence of a labral repair decreases the likelihood of a capsular defect (OR 0,1). Recent literature shows comparable results. In the series published by Strickland and Kraeutler et al there was no significant difference in capsular healing on a postoperative MRI between the repair or unrepaired capsulotomy group [39,40]. They did notice a higher rate of capsular healing in the repaired group but this difference was not significant. In the double blind randomized controlled trial of Strickland et al a total of 30 hips were included and all hips underwent interportal capsulotomy (maximum of 3cm length) [39]. Both the repair and unrepaired capsulotomy group consisted of 15 hips. After 24 weeks of follow-up all hips in both groups showed signs of capsular healing and contingency of the capsule on MRI [39]. In a different study of Weber et al they report that >90% of patients that underwent capsular repair shows an intact capsule measured on MRI [41]. They did not report any correlation between the presence of a capsular defect and possible patient specific or clinical characteristics (e.g. CE angle, BMI and gender) [41].

A recent study by Gao et al evaluated capsular integrity in a total of 194 patients [42]. They routinely closed all capsulotomies with 2 or 3 sutures. After a mean follow-up of 14.3months they observed a capsular defect on MRI in 8.8% of all patients [42]. In their study the patients with a capsular defect on MRI had significant higher VAS pain scores and significant lower scores on the modified Harris Hip Score (mHHS) [42]. Besides they report that patients with a defect capsule had a significant higher BMI than patients with an intact capsule [42].

Regarding the results presented in **Chapter** 7 and current literature it seems logical to conclude that both capsular repair as well as the unrepaired capsulotomy can lead to a healed and contingent capsule measured on MRI.

FUTURE PERSPECTIVES

RESEARCH

The results described in **Chapter 2** identify obesity as a relative contra-indication for hip arthroscopy. These observations are mainly drawn from limited literature with only a few years of follow-up. It would be valuable to examine the outcomes over an extended follow-up period. The introduction of new long-term follow-up studies or the establishment of national registries would be highly valuable for monitoring prolonged results and identifying potential cutoff points related to BMI and obesity. In addition to these cutoff points, it would also be beneficial to identify particular pathological conditions (such as an isolated CAM bump or bacterial arthritis) in which obese patients experience advantages from arthroscopic treatment over non-surgical or open-surgical treatment.

The impact of patient-specific psychological factors as described in **Chapter** 4 on the postoperative outcome following hip arthroscopy could be substantial. Should these factors be integrated into the standard pre-operative assessment? Should individuals exhibiting pain catastrophizing (PC) or central sensitization (CS) undergo pre-operative counseling therapy as a preliminary step? Answering these questions requires larger randomized trials. A potential design for a future trial involves assessing pre-operative central sensitization and pain catastrophizing scales. Patients identified with established PC or CS would be randomly assigned to either a pre-operative counseling therapy group or a control group. The outcomes would be evaluated through pain scores and patient-reported measures. The findings from this prospective trial could lay the groundwork for a new stepped-care approach in hip arthroscopy—identifying patients with PC and/or CS and providing tailored pre-operative counseling therapy before proceeding to the surgical intervention.

Regarding perioperative pain management there are some new developments as our paper in **Chapter 5** was already published some years ago. The new promising pericapsular nerve group block (PENG) is already discussed in the Discussion section and has substantial potential for future trials. It would be very interesting to see what the results are of a patient tailored approach versus a standardized pain protocol. This potential future trial can be designed as follows: a control group with patients that receive standard oral NSAID combined with local portal infiltration and a PENG block. The other patients are assigned to the tailored approach group and these patients receive oral NSAID with local portal infiltration. If postoperative pain control is insufficient these patients can optionally receive a PENG block. Outcome is measured with postoperative pain scores, opioid usage, length of stay and number of complications.

Hypothesis can be that oral NSAID with portal infiltration is sufficient for patients. A secondary analysis can investigate if the option of an additional PENG block might have a beneficial effect for a specific subgroup of patients undergoing hip arthroscopy.

The results in **Chapter 6** show strong evidence that after interportal capsulotomy there is no reason to routinely repair the hip capsule. Unfortunately, the follow-up in the CLOSE trial was merely 12 months and it's interesting to monitor the results of the CLOSE trial after a longer follow-up period. The hip capsule plays a critical role in hip joint stability and it is imaginable that an unrepaired capsulotomy potentially leads to micro-instability in the long term and possible poor long-term outcome.

Combined with the results described in **Chapter 7** it is interesting to design a cadaver study and investigate the role of several anatomical structures on capsular stability. Questions arise about the significance of the preoperative CE angle and the effects of a (non)repaired labrum on capsular stability. The outcomes of this cadaver study could serve as a foundation for a subsequent in vivo follow-up investigation, aiming to determine whether specific patient characteristics (such as the CE angle and labral repair status) could serve as criteria for deciding whether routine capsular repair is necessary.

CLINICAL SETTING

Performing hip arthroscopy is considered relatively contraindicated in individuals with obesity, primarily due to the higher prevalence of osteoarthritis, the higher chance that obese patients require a second operation and the technical challenges during the procedure. In contrast with this it is important to realize that obese patients show similar significant improvement on patient reported outcomes after surgery compared to non obese patients. For the orthopedic surgeon it's important to be cautious with performing hip arthroscopy on the obese patient and be aware of possible technical challenges.

Regarding psychological factors it is too soon to state that PC or CS are contra-indications for hip arthroscopy. For the hip arthroscopy surgeon, there may be practical value in assessing these factors preoperatively and initiating a discussion about the potential need for pre-operative counseling therapy if a patient is diagnosed with PC or CS. Particularly when a patient presents with multiple relative contraindications for surgery, identifying PC and/or CS could serve as a valuable tool in the decision-making process regarding whether to proceed with hip arthroscopy.

The findings outlined in **Chapter 5** combined with current literature indicate the effectiveness of a standardized perioperative pain management approach involving oral NSAID in conjunction with local or portal infiltration. An additional advantage of oral NSAID is its potential to prevent heterotopic ossification. While this pain management

regime can be combined with a peripheral nerve block, the superiority of a specific block remains uncertain. Consequently, the selection of a nerve block may vary and be influenced by local preferences and clinical experience.

There are some important considerations regarding capsular management after hip arthroscopy. Following a T-shaped capsulotomy, the existing literature offers clear guidance, consistently supporting the rationale for capsular repair. However, in the case of interportal capsulotomy, there appears to be no compelling reason to routinely repair the hip capsule. It is essential to recognize that various patient characteristics may play a role in deciding whether to proceed with capsular repair. The choice to undertake capsular repair may be tailored to the individual patient and is also influenced by the preferences of the orthopedic surgeon.

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CHAPTER 9

9

Chapter 9

SUMMARY
NEDERLANDSE SAMENVATTING

SUMMARY

After the establishment of the International Society for Hip Arthroscopy (ISHA) in 2008, the popularity and knowledge surrounding hip arthroscopy as a surgical procedure have increased. There is more understanding of the procedure and the number of possible indications that can be treated through arthroscopy of the hip have increased. Particularly, the results of various studies comparing hip arthroscopy versus physiotherapy in patients with Femoroacetabular Impingement Syndrome (FAIS) showed that hip arthroscopy is superior within certain patient groups compared to physiotherapy.

The number of hip arthroscopies performed has steadily increased over the past few decades; however, recent registry studies show that this trend has leveled off in the last few years. This stabilization is likely due to growing knowledge of the procedure, stronger evidence from ongoing research, and a clearer understanding of the appropriate indications for surgery.

Chapter 1 provides a general introduction to hip arthroscopy and outlines the goals of this thesis. The goals are to gain more insight into the correct indication criteria and determine which patient groups are suitable and will benefit the most from hip arthroscopy. Additional goals of this thesis are to optimise the outcome after hip arthroscopy, particularly focusing on the early postoperative period and also considering the clinical outcome in the medium term.

PART 1 PATIENT SELECTION IN HIP ARTHROSCOPY

Chapter 2 describes a systematic review into the outcomes of hip arthroscopy in patients with obesity. After a literature search, 2 studies were included for analysis. There appears to be no significant difference in the number of complications after hip arthroscopy between obese patients and non-obese patients. However, the re-operation rate and the risk of conversion to a total hip replacement were significantly higher in the obese group compared to the non-obese group. Regarding patient-reported functional outcomes, the obese group also scored significantly lower than the non-obese group. It is important to mention that both the obese group as the non-obese group shows the same significant functional improvement after a hip arthroscopy compared to baseline.

Given the higher risk of reoperation and the lower functional outcome for patients with obesity, it can be concluded that obesity is a relative contraindication for hip arthroscopy.

The most common indication for performing hip arthroscopy is Femoroacetabular Impingement Syndrome (FAIS) [4]. However, techniques are improving and there are also other types of hip impingement that can potentially be treated via hip arthroscopy.

Chapter 3 describes the results of a systematic review on three lesser-known types of hip impingement: subspine impingement (SSI), ischiofemoral impingement (IFI), and pelvitrochanteric impingement. **Chapter 3** outlines the symptoms, characteristics, and possible treatment options for these 3 types of hip impingement. Although only described in case series, it appears that patients with SSI and IFI may also be suitable for treatment by hip arthroscopy.

Two important parameters to determine success after hip arthroscopy are the reported functional outcome and the reported pain. Regarding pain perception, not all patients are the same. **Chapter 4** includes a prospective study of patients with pain catastrophizing (PC) and central sensitization (CS). Previous orthopedic research (e.g., patients with total knee replacements) have shown that patients with CS or PC have lower functional outcomes and a higher risk of persistent postoperative pain. The results in **chapter 4** shows that both PC and CS are associated with higher reported postoperative pain 12 weeks after hip arthroscopy.

It can be concluded that preoperatively measuring PC and CS can serve as a tool for orthopedic surgeons to optimally prepare and inform patients about the possible results after hip arthroscopy and potentially improve the outcome after hip arthroscopy.

PART 2 OPTIMISING OUTCOME AFTER HIP ARTHROSCOPY

As mentioned before, an important parameter for a successful outcome is the reported postoperative pain. **Chapter 5** describes a literature review in which various options for perioperative pain management are described. Although described in only one study, the use of postoperative NSAIDs leads to significantly lower pain scores measured at 12 hours and 24 hours after hip arthroscopy. Regarding local infiltration techniques, there is no difference in postoperative pain between intra-articular infiltration or local (portal) infiltration. However, intra-articular infiltration after hip arthroscopy does lead to significantly lower pain scores compared to a placebo infiltration.

Regarding peripheral nerve blocks, various sorts of nerve blocks have been compared to general anesthesia. Due to the wide variety of described techniques, different doses used, and different outcome measures, it is not possible to determine which peripheral nerve block yields the best result after hip arthroscopy.

In conclusion; it can be said that regarding postoperative pain management, there appears to be an indication for both the use of NSAIDs as well as a local infiltration (both portal and intra-articular are suitable). No conclusion can be made about which peripheral nerve block is the best choice regarding optimal pain management.

Chapter 6 presents the results of the CLOSE trial, a randomized patient-blinded study comparing whether or not repair of the hip capsule at the end of a hip arthroscopy has an effect on postoperative pain and functional outcome. There was no difference in reported pain scores between the capsular repair group and the unrepaired capsule group after 12 weeks of follow-up. Both groups showed a significant improvement in pain scores compared to the baseline.

The functional outcome was measured and reported using the Copenhagen Hip and Groin Outcome Score (HAGOS). After 12 months, there was no difference in the HAGOS score between the two groups. Based on the results of the CLOSE trial, it can be concluded that there seems to be no reason for routinely repair of an interportal capsulotomy after hip arthroscopy.

Chapter 7 contains the results of a follow-up study on the previously described CLOSE trial. In this case series, the effect of capsular repair on the healing and integrity of the hip capsule was investigated. The integrity of the hip capsule was measured on postoperative MRI images. Results shows that the incidence of an intact hip capsule is higher in the capsular repair group compared to the unrepaired capsulotomy group. However, this difference in incidence was not significant. Additionally, the results in **chapter 7** shows that there is no difference in functional outcome measured with the HAGOS score between the group with an intact capsule and the group with a capsular defect on MRI. Furthermore, **chapter 7** shows that patients with a high CE angle are more likely to have a capsular defect and that patients after a labral repair are less likely to have a capsular defect on MRI.

It can be concluded that there is no difference in capsular healing on MRI between the capsular repair group and the unrepaired capsulotomy group. Additionally, it can be concluded that there is no difference in functional outcome between patients with an intact capsule and patients with a capsular defect on MRI.

Chapter 8 contains the general discussion and is structured according to both main themes. The results of the various studies are discussed and compared with relevant literature, and the key findings of this thesis are highlighted. Finally, the clinical implications and future perspectives are described.

NEDERLANDSE SAMENVATTING

Na de oprichting van de International Society for Hip Arthroscopy (ISHA) in 2008 is de populariteit en kennis rondom de heup arthroscopie als operatie toegenomen. Er is meer kennis over de procedure en het aantal mogelijke indicaties dat kan worden behandeld middels een arthroscopie van de heup is toegenomen. Met name de resultaten van verschillende studies naar heup arthroscopie versus fysiotherapie in patiënten met Femoroacetabular Impingement Syndroom (FAIS) lieten zien dat heup arthroscopie binnen sommige patiënten groepen superieur is ten opzichte van behandeling middels fysiotherapie [1,2].

Het aantal uitgevoerde heup arthroscopie operaties leek de afgelopen 20 jaar alleen maar toe te nemen, uit register studies blijkt echter dat er een plateau is bereikt en er zelfs een afname te zien is in het aantal uitgevoerde ingrepen in de laatste jaren [3]. Vermoedelijk wordt deze afname veroorzaakt door meer kennis rondom de procedure, betere bewijslast door langer lopende studies en meer kennis rondom indicatiestelling.

Hoofdstuk 1 bevat een algemene inleiding in de heup arthroscopie en beschrijft de doelen van deze thesis. Deze zijn enerzijds te komen tot een juiste indicatiestelling inclusief het bepalen welke patiënten het meeste baat zullen hebben bij een heup arthroscopie. Anderzijds is het doel van deze thesis om de uitkomst na een heup arthroscopie te optimaliseren, zowel gericht op de vroege postoperatieve periode als ook de klinische uitkomst op de middellange termijn.

DEEL 1 PATIËNTEN SELECTIE IN HEUP ARTHROSCOPIE

Hoofdstuk 2 beschrijft een systematisch onderzoek naar de uitkomsten van heuparthroscopie bij patiënten met obesitas. Na een literatuuronderzoek zijn 2 studies geïncludeerd voor analyse. Er blijkt geen significant verschil te zijn in het aantal complicaties na heuparthroscopie tussen obesitas patiënten en niet obesitas patiënten. De kans op een re-operatie en de kans op conversie naar een totale heupprothese was wel significant groter in de obesitas groep ten opzichte van de niet obesitas groep. Wat betreft de patiënt gerapporteerde functionele uitkomst scoort de obesitas groep ook significant lager dan de niet obesitas groep. Wel belangrijk om te vermelden is dat zowel de obesitas groep als niet obesitas groep dezelfde significante functionele verbetering laat zien na een heup arthroscopie ten opzichte van de baseline. Gezien de grotere kans op een re-operatie en de lagere functionele uitkomst voor patiënten met obesitas mag geconcludeerd worden dat obesitas een relatieve contra-indicatie is voor een heup arthroscopie.

De meest voorkomende indicatie voor het uitvoeren van een heuparthroscopie is nog steeds FAIS [4], maar er zijn ook andere indicaties in opkomst. **Hoofdstuk 3** beschrijft de resultaten van een literatuuronderzoek naar 3 minder bekende vormen van heup impingement; subspine impingement (SSI), ischiofemoral impingement (IFI) en pelvitrochanteric impingement. In **hoofdstuk 3** worden de symptomen, kenmerken en mogelijke behandel opties benoemd voor deze 3 vormen van heup impingement. Hoewel alleen beschreven in case series lijkt het dat ook patiënten met SSI en IFI geschikt zijn voor een behandeling middels heup arthroscopie.

Twee belangrijk maten voor het bepalen van een goede uitkomst na een heuparthroscopie zijn de gerapporteerde functionele uitkomst en de gerapporteerde pijn. Wat betreft pijnbeleving zijn niet alle patiënten hetzelfde. **Hoofdstuk 4** omvat een prospectief onderzoek naar patiënten die pijn catastroferen (PC) en patiënten met centrale pijn sensitisatie (CS). Uit eerder gedaan orthopedisch onderzoek (bijvoorbeeld patiënten met totale knieprotheses) blijkt dat patiënten met CS of PC een lagere functionele uitkomst hebben en dat patiënten met CS of PC een hoger risico hebben op pijn na een operatie [5–7]. De resultaten in **hoofdstuk 4** laten zien dat zowel PC als CS geassocieerd zijn met de gerapporteerde postoperatieve pijn 12 weken na een heup arthroscopie. Een patiënt met PC of CS heeft baat bij goede preoperatieve voorlichting en kan mogelijk baat hebben bij cognitieve therapie.

Geconcludeerd kan worden dat het preoperatief meten van PC en CS als een hulpmiddel kan dienen voor orthopedisch chirurgen om patiënten optimaal voor te bereiden en in te lichten over het te verwachten resultaat, daarnaast kan dit mogelijk ook een effect hebben op het verbeteren van de uitkomst na een heup arthroscopie.

DEEL 2 OPTIMALISEREN UITKOMST NA EEN HEUP ARTHROSCOPIE

Zoals eerder beschreven is een belangrijke parameter voor een succesvolle uitkomst de gerapporteerde postoperatieve pijn. **Hoofdstuk 5** beschrijft een literatuuronderzoek waarbij verschillende opties van perioperatieve pijnbestrijding met elkaar worden vergeleken. Hoewel maar beschreven in 1 studie leidt het gebruik van postoperatief NSAIDS tot significant lagere pijnscores gemeten op 12uur en 24uur na een heup arthroscopie. Ten aanzien van lokale pijnbestrijding is er geen verschil wat betreft postoperatieve pijn tussen een intra-articulaire infiltratie of een lokale (portal) infiltratie. Een intra-articulaire infiltratie na een heup arthroscopie leidt wel tot significant lagere pijnscores in vergelijking met een placebo.

Wat betreft perifere zenuwblokkades zijn verschillende opties vergeleken met algehele anesthesie. Door de grote verscheidenheid aan beschreven technieken, verschillende doses die gebruikt zijn en de verschillende uitkomstmaten kan er geen uitspraak gedaan worden welk perifeer zenuwblok het beste resultaat oplevert na een heup arthroscopie.

Geconcludeerd kan worden dat wat betreft postoperatieve pijnbestrijding er een indicatie lijkt voor zowel het gebruik van NSAIDS als een lokale infiltratie (zowel portal als intra-articulair zijn geschikt). Er kan geen uitspraak gedaan worden over welke perifeer zenuwblok de beste keuze is voor optimale pijnbestrijding.

In **hoofdstuk 6** worden de resultaten beschreven van de CLOSE trial. Een gerandomiseerd patiënt geblindeerd onderzoek waarbij vergeleken wordt of het wel of niet hechten van het heup kapsel aan het einde van een heup arthroscopie effect heeft op de postoperatieve pijn en de functionele uitkomst. Na 12 weken is er geen verschil in gemeten pijnscores tussen de groep waarbij het kapsel gehecht werd en de groep waarbij het kapsel opengelaten werd aan het einde van de operatie. Beide groepen lieten wel een significante verbetering zien qua pijnscores ten opzichte van de baseline. De functionele uitkomst werd gemeten en gerapporteerd middels de Copenhagen Hip and Groin Outcome Score (HAGOS). Na 12 maanden was er geen verschil wat betreft de HAGOS-score tussen de beide groepen.

Aan de hand van de resultaten van de CLOSE trial kan geconcludeerd worden dat er geen reden is voor het routinematig hechten van het kapsel na een heup arthroscopie.

Hoofdstuk 7 bevat de resultaten van een vervolgstudie op de eerder beschreven CLOSE trial. In deze case series is onderzocht wat het effect is van het wel of niet hechten van het heupkapsel op de integriteit van dit kapsel. Het intact zijn van het heupkapsel is gemeten op postoperatieve MRI-beelden. Resultaten laten zien dat de incidentie van een intact heupkapsel hoger is bij de groep patiënten waarbij het kapsel gehecht ten opzichte van de patiënten waarbij het kapsel niet gehecht is. Echter is dit verschil in incidentie niet significant. Daarnaast laten de resultaten in **hoofdstuk 7** zien dat er geen verschil is in functionele uitkomst gemeten met de HAGOS-score tussen de groep waarbij het kapsel intact en en de groep waarbij er sprake is van een kapsel defect op MRI. Als nevenbevinding wordt beschreven in **hoofdstuk 7** dat het hebben van een hoge CE-hoek het waarschijnlijker maakt dat er sprake is van een kapsel defect, daarnaast is het zo dat er na het hechten van het labrum er minder kans is op een kapseldefect.

Geconcludeerd kan worden dat er geen verschil is in genezing van het kapsel tussen de groepen waarbij het kapsel werd gehecht of niet werd gehecht. Daarnaast kan geconcludeerd worden dat er geen verschil is in functionele uitkomst tussen de patiënten met een intact kapsel en patiënten met een kapsel defect op MRI.

Hoofdstuk 8 bevat de algemene discussie en is gestructureerd aan de hand van beide hoofdthema's. De resultaten van de verschillende onderzoeken worden besproken en vergeleken met de huidige literatuur, daarnaast worden de belangrijkste bevindingen van dit proefschrift benoemd. Als laatste worden de klinische implicaties en toekomstperspectieven beschreven.

Appendices

Appendices

DANKWOORD
PORTFOLIO
ABOUT THE AUTHOR

DANKWOORD

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PORTFOLIO

Name PhD Student	Niels Hendrik Bech
PhD period	September 2015 – April 2026
Promotor	Prof. dr. G.M.M.J. Kerkhoffs
Copromotor	dr. D. Haverkamp

PHD TRAINING

	Year	ECTS
General courses		
Good Clinical Practice	2014	1.0
Teach the Teacher, AMC Amsterdam	2016	0.5
Harvard Medical School online course; Causal Diagrams	2017	0.5
eBROK	2018	1.5
Specific courses		
Advanced Trauma Life Support, New York	2013	1.0
Fundamental Critical Care Support, Ede	2017	1.0
AO Basic Principles of Fracture Management, Chicago	2017	1.5
Basiscursus voetchirurgie, DFAS, Nijmegen	2017	0.5
Starterscursus voetchirurgie DFAS, Nijmegen	2017	0.5
NVA scopiecursus 2 "knie", Utrecht	2018	1.0
Advanced Trauma Life Support refresher course, Richmond	2018	1.0
Stralingshygiëne voor Medisch Specialisten, Amsterdam	2018	1.0
Cursus knieprothesiologie, AMC, Amsterdam	2019	1.0
Cursus heupprothesiologie, Radboud umc, Nijmegen	2020	1.0
Basiscursus Osteotomie, ViaSana, Mill	2020	0.5
Johnson & Johnson wetlab Anterior approach cadaver course, Erasmus MC, Rotterdam	2021	1.0
Hospital Major Incident Medical Management and Support Course (HMIMMS), ALSG	2021	1.0
OTC 3: Operatieve fractuurbehandeling - more than basic, Uden-Veghel	2021	0.5
OTC 4: Advanced – Paediatrics, Uden-Veghel	2022	0.5
Definitive Surgical and Anesthetic Trauma Care course (DSATC), Nijmegen	2022	2.0
NVA Advanced Knee course, Erasmus MC Rotterdam	2022	1.0
Smith & Nephew Principles of Alignment and Joint Line Orientation, Hoofddorp	2022	0.5
Advanced Trauma Life Support refresher course, Tilburg, ALSG	2023	0.5

Zimmer Biomet Instructional Course Oxford Partial Knee, Oxford	2023	1.5
Johnson & Johnson wetlab Advanced Ligament knee reconstruction, Erasmus MC, Rotterdam	2025	1.0

Podium presentations		
The CLOSE trial, preliminary results of a randomized controlled trial. European Hip Society, Den Haag	2018	0.5
Fracture related infections, case-based discussion, Traumadagen, Amsterdam	2019	0.5
The influence of pain catastrophizing and central sensitization on the reported pain after hip arthroscopy. ESSKA home congress (virtual)	2021	0.5
Capsular closure versus unrepaired capsulotomy after hip arthroscopy, the CLOSE trial. European Hip Society, Lille (virtual)	2021	0.5
Capsular closure versus unrepaired capsulotomy after hip arthroscopy, the CLOSE trial. NvA lustrumcongres. Award: dr. Eikelaarprijs for best presentation.	2021	0.5
Capsular closure versus unrepaired capsulotomy after hip arthroscopy, the CLOSE trial. ESSKA Parijs	2022	0.5

Poster presentations		
Perioperative pain management in hip arthroscopy; what options are there? European Hip Society, Munchen	2016	0.5
Capsular closure vs unrepaired capsulotomy in hip arthroscopy. The CLOSE trial. ESSKA, Glasgow	2018	0.5
Arthroscopic psoas release in patients after total hip arthroplasty, a case series. European Hip Society, Den Haag	2018	0.5
Restoring delamination cartilage lesions caused by CAM impingement with BST cargel during hip arthroscopy. ESSKA home congress (virtual)	2021	0.5

Memberships	
Nederlandse Orthopaedische Vereniging, NOV	2018 - present
Nederlandse Vereniging van Arthroscopie, NVA	2018 - present
Werkgroep NVOT, Nederlandse Vereniging voor Orthopedische Traumatologie	2020 - present
Werkgroep Heup, NOV	2020 - present
Werkgroep Knie, Dutch Knee Society, NOV	2020 - present

(Inter)national conferences		
Amsterdam Symposium "Challenges in Trauma" & Traumaplatform Young Generations Seminar, Amsterdam/ Kuopio	2015	2.0
Edinburgh Trauma Symposium, Edinburgh	2016	1.5
European Hip Society, Den Haag	2018	1.0
NOV congresses, yearly	2016 - 2024	5.0
NVA lustrumcongres, Noordwijk	2021	1.0
European Hip Society (virtual), Lille	2021	0.5
ESSKA congress, virtual	2021	0.5
ESSKA congress, Parijs	2022	1.5
Combined Belgian and Dutch Knee Society meeting, Antwerpen	2022	1.0
Combined 61st NOF Congress and NOV Jaarcongres 2024	2024	1.0
Traumadagen, RAI Amsterdam	2024	0.5
Belgian and Dutch Knee Society meeting, Breda	2024	1.0
NVA lustrumcongres, Noordwijk	2025	1.0

Other		
Skate for Science challenge, Kuopio Finland	2015	1.0
Co-organizer "ride for research", Edinburgh Schotland	2016	1.0
Journal club	2018 - 2020	3.0

Awards	
Dr. Eikelaarprijs, beste presentatie, NVA lustrumcongres Noordwijk	2021

Publications	
N.H Bech, I.F Kodde, F. Dusseldorp, P.A.M.C Druyts, S.P.L Jansen, D. Haverkamp. Hip arthroscopy in obese, a successful combination? *J. Hip Preserv Surg* 2015 Nov 27;3(1):37-42.	2015
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N.H Bech, P. Kloen. Recalcitrant Septic Nonunion of the Ulna. *Cureus* 2020 Mar 6;12(3): e7195.	2021
P. Kloen, R.E. Hamdy, N.H. Bech. Plethora of traumatic lesions of bilateral knee extensor mechanism in Osteogenesis Imperfecta. *Frontiers in Endocrinology* 2021 Jan 21;11:603638.	2021
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Bech NH, van Dijk LA, de Waard S, Vuurberg G, Sierevelt IN, Kerkhoffs GM, Haverkamp D. Integrity of the hip capsule measured with magnetic resonance imaging after capsular repair or unrepaired capsulotomy in hip arthroscopy. *World J Orthop* 2022; 13(4): 400-407	2022

ABOUT THE AUTHOR

Niels Bech is geboren op 9 februari 1987 in 's-Hertogenbosch als zoon van Wim en Rozan Bech. Hij heeft het vwo-diploma behaald aan het Sint-Jans-Lyceum in 's-Hertogenbosch in 2005. Daarna is hij geneeskunde gaan studeren in Rotterdam.

Na het afronden van de studie geneeskunde heeft hij eerst een jaar gewerkt bij de algemene chirurgie in het Maasstad ziekenhuis Rotterdam. Hierna maakte hij de stap naar de orthopedische chirurgie en ging werken als anios orthopedie in het toenmalige Slotervaart ziekenhuis in Amsterdam. Hier begon de samenwerking met dr. Daniel Haverkamp waarbij meerdere projecten zijn opgestart, waaronder de start van de CLOSE studie. Uiteindelijk bleek dit de basis te zijn van het proefschrift zoals het er nu ligt.

In 2017 is Niels begonnen met de opleiding tot orthopedisch chirurg in de regio Amsterdam. Hij deed zijn vooropleiding in het OLVG in Amsterdam (dr. M. Gerhards). Daarna continueerde hij de opleiding tot orthopedisch chirurg in het Slotervaart ziekenhuis (dr. H. v.d. Vis), het AMC (prof. dr. G.M.M.J Kerkhoffs & dr. M. Schafroth) en in het Tergooi MC (dr. T. Vervest).

In 2022 rondde Niels de opleiding af en startte hij als orthopedisch chirurg, chef de clinique in het Tergooi MC. Na een jaar is hij toegetreden tot de maatschap en vakgroep Orthopedie en Traumatologie van het Tergooi MC.

Hij is nu werkzaam als orthopedisch chirurg – traumatoloog met speciale aandacht voor knie- en heuppathologie.

Niels is getrouwd met Ploni en ze wonen in Baarn samen met hun dochter Nora en zoon Bouwe.

Amsterdam Movement Sciences

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