Greater Trochanteric Pain after Total Hip Arthroplasty
Incidence, clinical outcome, associated factors, tenderness evaluation with algometer, and a new surgical treatment

Ph.D. Thesis in Orthopaedics by

Arkan Sam Sayed-Noor M.D.

Orthopaedics
Department of Surgical and Perioperative Sciences

Umeå 2008
Principal tutor
Associate Professor Göran Sjödén

Co-tutors
Associate Professor Per Wretenberg
Associate Professor Hans Malker

Faculty opponent
Professor Lars Weidenhielm, Karolinska Institute

Cover design by Vivan Rönqvist

Published articles have been reprinted with permission from the publisher.

Printed by Hemströms tryckeri, Härnösand.

Copyright© 2008 Arkan Sam Sayed-Noor
ISBN 978-91-7264-643-8
In memory of my best mentor and friend ever, my father Sam Sayed-Noor (1935 – 1999), for having the honour of being his son. Oh God, how I wish he was here right now.

That knowledge which remains only on your tongue is very superficial. The intrinsic value of knowledge is that you act upon it. Knowledge and practice are twins, and both go together. There is no knowledge without practice, and no practice without knowledge.

The philosopher of all time Imam Ali Ibn Abi-talib (PBUH) (600 – 661 AD).
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>7</td>
</tr>
<tr>
<td>Abbreviations</td>
<td>9</td>
</tr>
<tr>
<td>List of original papers</td>
<td>10</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>11</td>
</tr>
<tr>
<td><strong>Introduction</strong></td>
<td>13</td>
</tr>
<tr>
<td>Anatomical and pathophysiological considerations</td>
<td>14</td>
</tr>
<tr>
<td>Evaluation of trochanteric tenderness with Algometer</td>
<td>16</td>
</tr>
<tr>
<td>Epidemiological considerations and associated factors</td>
<td>17</td>
</tr>
<tr>
<td>Therapeutic considerations</td>
<td>18</td>
</tr>
<tr>
<td>Greater trochanteric pain after total hip arthroplasty</td>
<td>19</td>
</tr>
<tr>
<td>Clinical and radiological measurements of LLD</td>
<td>20</td>
</tr>
<tr>
<td><strong>Aims</strong></td>
<td>23</td>
</tr>
<tr>
<td><strong>Patients and Methods</strong></td>
<td>24</td>
</tr>
<tr>
<td>Study I</td>
<td>24</td>
</tr>
<tr>
<td>Study II</td>
<td>26</td>
</tr>
<tr>
<td>Study III</td>
<td>28</td>
</tr>
<tr>
<td>Study IV</td>
<td>31</td>
</tr>
<tr>
<td><strong>Results</strong></td>
<td>33</td>
</tr>
<tr>
<td>Study I</td>
<td>33</td>
</tr>
<tr>
<td>Study II</td>
<td>34</td>
</tr>
<tr>
<td>Study III</td>
<td>36</td>
</tr>
<tr>
<td>Study IV</td>
<td>37</td>
</tr>
<tr>
<td><strong>Discussion</strong></td>
<td>38</td>
</tr>
<tr>
<td><strong>Summary and conclusion</strong></td>
<td>47</td>
</tr>
<tr>
<td><strong>Future implications</strong></td>
<td>48</td>
</tr>
<tr>
<td>Summary in Swedish-Populärvetenskaplig sammanfattning</td>
<td>49</td>
</tr>
<tr>
<td>References</td>
<td>51</td>
</tr>
<tr>
<td>Appendix</td>
<td>60</td>
</tr>
</tbody>
</table>
Abstract
Greater Trochanteric Pain after Total Hip Arthroplasty

Greater trochanteric pain (GTP) is a regional pain syndrome characterized by lateral hip pain and tenderness. Its incidence after total hip arthroplasty (THA) is variable. Bursal inflammation, degenerative changes of the attachment of the gluteal muscles, direct operative trauma and biomechanical disturbance of the operated hip have been discussed as being related to GTP. The diagnosis is purely clinical because radiological and laboratory investigations show no definite pathology. Although most treatment modalities are conservative, some patients may develop refractory complaints leading to surgical intervention.

In study I we studied the incidence of GTP in 172 consecutive patients who underwent THA during 2002 at Sundsvall Hospital. Patients with GTP (n=21, incidence 12%) were matched with controls from the same cohort. The THA outcome was assessed using the Western Ontario and McMaster Universities Arthrosis (WOMAC) Index. Trochanteric tenderness was studied using an electronic pressure algometer. We found an association between the occurrence of GTP and postoperative uncorrected lengthening of the operated limb of ≥ one centimetre. The WOMAC index revealed a reduction of the clinical outcome in the GTP group.

In Study II we tested the value of using an algometer in the diagnosis of GTP after THA. We measured the pressure-pain threshold (PPT) over the greater trochanter and ilio-tibial band in 18 patients and 18 matched controls. Both groups were evaluated using the visual analogue scale (VAS). We found the algometer to have a good predictive validity and reproducibility.
However, there was large inter-individual variability across subjects. The PPT ratio of 0.8 (affected vs. unaffected side) can be used as a cutoff ratio to establish GTP. There was no correlation between PPT measurements and VAS. Because of a low positive predictive value and large inter-individual variability, the pressure algometer has a limited value as a screening tool.

In **study III** we proposed a new surgical treatment for refractory GTP after THA consisting of distal lengthening of the ilio-tibial band (ITB) by Z-plasty under local anaesthesia. This method was used in 12 women between March 2004 and June 2006. The patients were followed up by phone interview 3-4 months postoperatively and by an EQ-5D questionnaire and clinical examination including evaluation with the algometer at 1-3 years postoperatively. We found that the patients’ quality of life was markedly improved following the operation (EQ-5D = 0.26 preoperatively vs. 0.67 postoperatively; p <0.005). There were no postoperative complications.

In **study IV** we evaluated the accuracy of a commonly used clinical method of LLD measurement (anterior superior iliac spine-medial malleolus) by comparing it to a reliable radiological method (tear drop-lesser trochanter) in 139 patients before and after THA. We found the correlation between the clinical and radiological methods to be weak preoperatively (r=0.21, ICC= 0.33) while the correlation was moderate postoperatively (r= 0.45, ICC=0.62). It is therefore recommended that the radiological method be used to measure leg length discrepancy in patients who undergo THA.
Abbreviations

ADL Activities of daily living
AP view Antero-posterior view
ASIS Anterior superior iliac spine
CT Computerized tomography
DNIC Diffuse noxious inhibitory control
ECRB Extensor carpi radialis brevis
EQ-5D EuroQol index
GTP Greater trochanteric pain
ICC Intra-class correlation coefficient
ITB Ilio-tibial band
kPa kiloPascal
LLD Leg length discrepancy
MRI Magnetic resonance imaging
NSAIDs Non-steroidal anti inflammatory drugs
OA Osteoarthritis
PPT Pressure-pain threshold
PPV Positive predictive value
RA Rheumatoid arthritis
ROM Range of motion
SD Standard deviation
THA Total hip arthroplasty
VAS Visual analogue scale
WOMAC Western Ontario and McMaster universities arthrosis index
Original papers

Study I

Sayed-Noor AS, Sjödén GO
Greater Trochanteric Pain after Total Hip Arthroplasty: the incidence, clinical outcome and associated factors.

Study II

Sayed-Noor AS, Englund E, Wretenberg P, Sjödén GO
Pressure-Pain Threshold Algometric Measurement in Patients with Greater Trochanteric Pain after Total Hip Arthroplasty.

Study III

Sayed-Noor AS, Pedersen E, Wretenberg P, Sjödén GO
Distal Lengthening of Ilio-tibial Band by Z-plasty for Treating Refractory Greater Trochanteric Pain after Total Hip Arthroplasty (Pedersen-Noor operation).

Study VI

Sayed-Noor AS, Hugo A, Sjödén GO, Wretenberg P
Leg Length Discrepancy in Total Hip Arthroplasty. Comparison of Two Methods of Measurement.
Acknowledgements

This work was carried out at Department of Orthopaedics, Sundsvall Hospital (studies I, II & III) and Department of Orthopaedics, Karolinska University Hospital (study IV). Many people have contributed to this work. I would like to express my deep gratitude to all of them, and particularly to:

My beloved wife, Dhuha, for everything you have sacrificed for me since we first met, for your endless love, support and encouragement. Without you my life has absolutely no meaning.

My wonderful mother, for your extreme kindness and generosity. Without your prayers this work would never have been possible.

My sweet daughters, Noor and Aia, for every smile you gave me. I love you so much.

My fantastic principal tutor, Associate Professor Göran Sjödén, for being such an ideal mentor in every way, for introducing me to the world of research, for guiding and encouraging me all the way through, for not becoming tired or bothered by my endless primitive questions and for being available anyhow, anywhere and anytime. I can not imagine writing an article without your name beside mine.

My fantastic co-tutor, Associate Professor Per Wretenberg. Despite the geographical distance between Sundsvall and Stockholm, your input, engagement and advice were more than essential for the completion this work. Thank you for your indispensable help. I was really privileged to get the chance to work with you.

My fantastic co-tutor, Associate Professor Hans Malker. Your tremendous experience and skills in research are indescribable. Thank you for your brilliant advice and for the financial help from the Research and Development centre.

My co-author and friend, Erling Englund PhD, statistician. When we first met I knew nothing about statistics. Your skills, patience and kindness were the only things that made me understand the mysteries of this science.

My co-author and colleague, Consultant Orthopaedic Surgeon Eskild Pedersen, for allowing me to evaluate your brilliant procedure (Pedersen-Noor Operation).

My co-author, Orthopaedic Surgeon Anders Hugo, for allowing me to analyse and write study IV.

All of my fantastic colleagues at the department of Orthopaedics, Sundsvall Hospital for your encouragement and advice, especially the Head of Department, Consultant Orthopaedic Surgeon Lennart Bengtson for providing me with a big room so that I could do my paper work undisturbed, the orthopaedic tutor of our department Consultant Orthopaedic Surgeon
Nader Mafi and my supervisor during my orthopaedic residency Consultant Orthopaedic Surgeon Carl-Håkan Ohlson for your encouragement.

My colleague and friend, Consultant Orthopaedic Surgeon Zewar Al-Dabbagh, for reviewing the articles before submitting them. Your constructive positive criticism doubtlessly improved my work.

My mentor and colleague in IRAQ, Associate Professor Dhia A K Jaddue. Thank you for introducing me to the marvellous world of Orthopaedics.

Professor Olle Svensson for your support and kindness all the way through.

All the staff of the Research and Development centre (FoU) and Primary care centre, for your great help especially Vivan Rönnqvist for your kind assistance with the cover design.

All the staff of the Department of Orthopaedics at Sundsvall Hospital especially at the outpatient department, Sister Ann-Sofi Andersson and sister Unni Iwefors, for your help with my patients’ visits.

All the secretaries of the Department of Orthopaedics, especially Ewa Lundberg for your invaluable assistance with the documentations.

All the staff of Sundsvall Hospital library for your great services in providing me with the reference articles.

The Swedish Orthopaedic Association and DePuy Johnson & Jonhson for your kind assistance and financial support (Sir John Charnley´s stipedium).

The Emil Andersson and Henry Kjellén foundations for your financial support.
Introduction

Trochanteric bursitis, or preferably greater trochanteric pain (GTP) syndrome, is a common regional pain syndrome characterized by lateral hip pain and diffused or localized trochanteric tenderness (jump sign). The patient is classically middle-aged (peaks between the 4th and 6th decades) and female (female to male ratio is 4-6:1) though both sexes at any age can be affected (Collee et al. 1990, Shbeebe et al. 1996, Bird et al. 2001, Tortolani et al. 2002, Dunn et al. 2003, Walsh et al. 2003). Commonly, patients present with chronic intermittent dull aching discomfort in the trochanteric area, with or without radiation along the ilio-tibial band (ITB) down to its insertion at Gerdy’s tubercle on the proximal tibia. Sometimes the presentation is acute or subacute, especially when there is a history of trauma or overuse activity. Other clinical manifestations include exacerbation of symptoms on prolonged standing or walking, using stairs (mainly descending), lying on the affected side, rising from a seated position and actively abducting or rotating the hip internally against resistance (Patrick-Fabere test) (Collee et al. 1990, Shbeebe et al. 1996, Bird et al. 2001, Tortolani et al. 2002, Dunn et al. 2003, Walsh et al. 2003). In the absence of hip joint disease, hip movements are normal.

The diagnosis is solely clinical, and laboratory investigations give no clue (Collee et al. 1990, Shbeebe et al. 1996, Bird et al. 2001, Tortolani et al. 2002). However, the presentation may resemble other conditions which should be ruled out, such as radiculopathy secondary to nerve root entrapment, spinal stenosis or facet joint disease, hip joint disease such as osteoarthritis (OA), tumour or fracture and peripheral nerve entrapment. The treatment is mainly conservative and consists of NSAIDs, analgesics, physiotherapy including stretching exercises and local corticosteroid injections (Shbeebe et al. 1996, Alvarez-Nemegyei et al. 2004). Schapira et al. (1986) reported a response rate of 90 % to this treatment. The rapid
improvement of symptoms in response to local corticosteroids is sometimes of diagnostic value. Surgical intervention is indicated when a patient with severe complaints shows weak or no response to conservative therapy.

**Anatomical and pathophysiological considerations**

The bony surface of the greater trochanter of the femur has four facets (Pfirrmann et al. 2001): anterior, inferior, lateral and supero-posterior. The gluteus medius muscle attaches to the supero-posterior and lateral facets, while the gluteus minimus muscle attaches to the anterior facet. These two muscles are considered the “rotator cuff” of the hip joint, playing an important role in abducting the hip and stabilizing the pelvis during ambulation (Bunker et al. 1997, Kegan 1999). Weakness of these muscle leads to Trendelenburg’s sign.

Various studies (Spear et al. 1952, Bywaters 1965, Pfirrmann et al. 2001, Dunn et al. 2003, Woodley et al. 2008) showed that there are numerous bursae (at least 6) around the greater trochanter. One or more (up to 4) bursae lie beneath the gluteus maximus muscle (subgluteus maximus bursae or trochanteric bursa) covering the posterior facet and the common attachment of the gluteus medius, gluteus minimus and vastus lateralis muscles. Smaller bursae can be found around and beneath the gluteus medius and minimus muscles (Figure 1). The discrepancy in the number and size of these bursa(e) may support the hypothesis that certain bursa(e) may be acquired secondary to degenerative changes with prolonged and recurrent impaction of the facia lata on the greater trochanter.

The pathogenesis of GTP is still a matter of discussion. Though the condition is sometimes called bursitis, no signs of local inflammation such as redness, warmth and swelling are encountered (Silva et al. 2008). Only few patients recall a history of trauma, though a history of overuse is not uncommon.
Previous hip surgery, especially involving the trochanteric region such as total hip arthroplasty (THA) or implant fixation may apply direct trauma to the nearby muscle attachments with their surrounding bursae, giving rise to GTP (Vicar et al. 1984, Snider 1997, McAuley et al. 1998, Schinsky et al. 2003, Bozic et al. 2004).

Researchers have used different modalities such as plain radiograph, scintigraphy, MRI and ultrasound to reveal any local changes that might explain the aetiology of GTP. Calcifications and irregularities of the greater trochanter seen on plain radiographs are non-specific manifestations and have limited diagnostic value (Finlay et al. 2006). This is also true regarding increased uptake on scintigraphy. Bird et al. (2001) studied MRI in 24 patients with GTP and found a gluteus medius tear in 46% of cases, gluteus medius tendinitis in 62% and trochanteric bursal distension in less than 10% of cases. Kingzett-Taylor et al. (1999) reviewed the findings of 250 MRI examinations performed to evaluate patients with buttock pain, lateral hip pain and groin pain. The identified 35 patients (14%) with MRI changes of gluteal tendinopathy (tendinosis and tear). Mayordoromo et al. (1997) studied ultrasound findings in 15 patients with GTP and 13 controls. Bursal enlargement with increased wall thickness was founded in 85% of the GTP group and 30% of controls.
**Figure 1:** Anatomical illustration of the greater trochanter in relation to the attachment of the gluteal muscles and different groups of bursae.

**Evaluation of trochanteric tenderness using an algometer**

Tenderness over the trochanteric area represents the cornerstone of GTP diagnosis. Krout and Anderson (1959) proposed that GTP is diagnosed when trochanteric tenderness and lateral hip pain are combined with one of the following: radiating pain along ITB, pain on resisted hip abduction or pain at hip rotation. The evaluation of tenderness (pressure-pain threshold, PPT) is amenable to bias and is difficult to standardise and replicate. Researchers have used different instruments to make the assessment of tenderness more objective. The pressure algometer is one of these instruments. It is a pistol-like instrument with a flat circular rubber footplate and a display unit (Figure 2). Linearly increasing perpendicular pressure is applied using the algometer and the patient is told to press the hand-held button to record the PPT at the moment when the applied pressure is painful. The validity and reliability of the algometer on different body parts has been thoroughly investigated (Fischer 1987, Ohrbach et al. 1989, Chung et al. 1993, Naussbaum et al. 1998, Farella et al. 2000, Silva et al. 2005) but we found no study investigating the feasibility of this instrument over the hip. We believed that the
algometer had a promising role in the diagnosis and evaluation of severity and response to treatment of GTP. It was therefore indicated to test its validity and diagnostic value on the hip.

Figure 2: Algometer.

Epidemiological considerations and associated factors
Despite the fact that GTP is a commonly seen condition in general practice, the exact prevalence in the general population is not clear. The incidence of GTP is more common in females than males (Andersson 1958, Collee et al. 1990, Tortolani et al. 2002, Segal et al. 2007).

Segal et al. (2007) studied the prevalence of GTP in a cross-sectional sample of a community-based population aged 50-79 years with a high risk of knee OA. He used a pain diagram and a Chatillon dolorimeter for the assessment of trochanteric pain and found a prevalence of unilateral and bilateral GTP of 15% and 8.5% in women and 6.6% and 1.9% in men,
respectively. Furthermore, GTP was found to be related to low back pain (LBP), ipsilateral and contralateral knee OA and ITB tenderness. No relation was found between the occurrence of GTP and obesity, age or race. Collee et al. (1990) and Tortolani et al. (2002) found a GTP prevalence of 20-35% in adults with LBP. In addition, Sayegh et al. (2004), in an uncontrolled study, found that females with LBP showed fewer back complaints when they received local corticosteroid injections in the trochanteric region.

Raman et al. (1982) studied one hundred consecutive patients with rheumatoid arthritis (RA) for the presence of GTP. This condition was found in 15. He concluded that GTP is an underdiagnosed, easily remediable cause of pain in RA and that specific examination for its presence should be a routine in all patients with RA, especially those with hip pain. Other factors associated with GTP such as femoral offset and leg length discrepancy (LLD) are classically suggested in the literature but not appropriately investigated.

**Therapeutic considerations**

The treatment of GTP is mainly non-operative. During the first half of the last century patients were treated with bed rest, heat or ice, exercises and local anaesthesia. Some researchers used radiation. During the second half, local corticosteroids were widely used. Gordon et al. (1961) described good response to single or multiple injections. More recent studies (Ege Rasmusson et al. 1985, Schapira et al. 1986) showed 70-100% response but with a relapse frequency of 25% within 10 months. However, no clinical outcome index was used in these studies. In patients with disabling refractory GTP, surgical intervention may be warranted. Several studies described different surgical methods with variable, yet generally satisfactory results. These methods consisted for example of ITB decompression over the greater trochanter with or without trochanteric bursectomy (Brooker 1979, Zoltan et al. 1986, Slawsky et al. 1997), Z-lengthening of ITB over the greater trochanter with or without
trochanteric bursectomy (Chirputkar et al 2007, Craig et al. 2007). Govaert et al. (2003) described a new operative intervention consisting of trochanteric reduction osteotomy with screw fixation. Arthroscopic treatment of refractory GTP was performed by Fox (2002). The main theme of the above mentioned surgical interventions was to reduce the tension of the ITB over the greater trochanter.

**Greater trochanteric pain after total hip arthroplasty**

Total hip arthroplasty is one of the most successful and cost-effective surgical interventions (Swedish hip arthroplasty registry, annual report 2006). Nevertheless, the outcome of this procedure can be adversely affected by the development of pain at the operated hip after the operation. One type of pain is GTP. The diagnosis may be challenging. Intrinsic causes such as septic or aseptic loosening of the prosthesis should be looked for and ruled out using suitable laboratory and radiographic investigations. Extrinsic causes such as lumbar spine diseases and neurovascular abnormalities are not uncommon in elderly patients and might give rise to groin and thigh pain (Bozic et al. 2004).

The incidence of GTP after THA is variable and depends mainly on the surgical approach used. Vicar et al. (1984) found that GTP occurred in 11% of 136 patients operated with transtrochanteric THA, 4.4% of 91 patients operated with the anterolateral (Hardinge) approach and 4.7% of 42 patients operated with posterolateral (Moore) approach. Schinsky et al. (2003) studied 100 hips operated with transtrochanteric THA and 100 hips operated with the posterolateral approach. He found GTP incidence of 8 % in the first group and 1% in the second group. McAuley et al. (1998) found GTP incidence of 5% in 121 THAs operated with a posterolateral approach. None of these authors investigated if there were other factors associated with GTP development other than the surgical approach used. Iorio et al. (2006) evaluated the incidence and associated factors of GTP in 543 primary THAs where 461 hips
were operated with an anterolateral approach and 82 hips with a posterolateral approach. The incidence of GTP was 4.9% in the first group and 1.2% in the second group. Females were more commonly affected. Leg length discrepancy, femoral offset and heterotopic ossification were not associated with GTP development. The Hip Harris Score was significantly lower in the GTP group compared to others.

The treatment of GTP after THA, as in non-operated patients, is mainly conservative (Iorio et al. 2006). However, in some cases GTP complaints can be refractory, and surgical treatment is indicated. The presence of the implant as well as the fibrosis of the soft tissues at the site of the THA incision should be taken into consideration when planning the surgical treatment of GTP.

**Clinical and radiological measurements of LLD**

The measurement of LLD is an important part of examination in patients planned for THA. Numerous clinical and radiological methods for measuring LLD have been described in the literature. The choice of a specific method is usually a matter of personal preference, cost and availability. Commonly, LLD is measured clinically and radiologically before and after THA. The clinical measurement is carried out while the patient in the supine position by using a measuring tape. The distance between the anterior superior iliac spine (ASIS) and the medial malleolus shows the real LLD, while the distance between ASIS and umbilicus shows the apparent LLD (Maloney et al. 2004). The latter can be affected by pelvic obliquity and lumbar spine deviation revealing non true leg length discrepancy. Another clinical method of measurement involves the use of blocks of increasing thickness placed under the shorter limb until the pelvis appears level with the patient in standing position. The radiological measurement is carried out on an AP view of the pelvis. Fixed points in the pelvic bones such
as the tear-drop points medial to the acetabulae or the lower edge of ischial tuberosities are used as reference points and the distance between these points and fixed points at the proximal femur such as the lesser trochanter or the centre of the femoral head is measured on each side (Ranawat et al. 1997, Maloney et al. 2004, Matsuda et al. 2006, Clark et al. 2006, Iagulli et al. 2006).

The degree of precision, validity, intra-observer and inter-observer reliability as well as agreement among these different methods are quite variable (Clarke et al. 1972, Gogia et al. 1986, Friberg et al. 1988, Beattie et al. 1990, Hoyle et al. 1991, Jonson et al. 1997). For example, Hoyle et al. (1991) found an excellent intra-class correlation coefficient (ICC) of 0.90-0.95 for intra-observer reliability and 0.98-0.99 for inter-observer reliability when he used the clinical method (ASIS-medial malleolus) in 25 subjects. These measurements were well correlated with the Metrecom measurements. Gogia et al. (1986) reported excellent correlation between clinical and radiological measurements (ICC of 0.99). Nichols et al. (1955), on the other hand, found that clinical measurement was reliable only if LLD was greater than 17.7mm, and reliability decreased when LLD was less than 6.4mm. Beattie et al. (1990) found an overall correlation of 0.68 between clinical and radiological measurements of LLD in 10 patients and 9 controls. Using blocks under the shorter limb to measure LLD was found to be an accurate (Pakvis et al. 2003) and a reliable method (Jonson et al. 1997). The later found an ICC for intra-observer and inter-observer reliability to be 0.87 and 0.70 respectively. Woerman et al. (1984) stated that using blocks was the most accurate clinical method and that it differed from radiological determination by an average of 2.2mm.

The radiological measurement of LLD is a commonly used method (Williamson et al. 1978, Edeen et al. 1995, Ranawat et al. 2001, Konyves et al. 2005, Matsuda et al. 2006, Clark et al. 2006, Iagulli et al. 2006). This method has been reported to be as reliable as orthoroentgenogram (Konyves et al. 2005). The interobserver reliability of this method was
tested by Woolson et al. (1999) and found to be high (0.5 mm) while intraobserver reliability was tested by White and Dougall (2002) and found to give a measurement error of +/-1 mm. Goodman et al. (1987) recommended the use of the tear-drop points as a landmark for measurements rather than other points in the pelvis, because the vertical position of the tear-drop points is not affected significantly by rotation of the pelvis. Other more advanced and modern methods of LLD measurement such as CT scanogram, X-ray scanogram and MRI scanogram are well documented (Helms et al. 1984, Aitken et al. 1985, Huurman et al. 1987, Aaron et al. 1992, Terry et al. 2005, Leitzes et al. 2005).

Leg length discrepancy after THA has been associated with general dissatisfaction (Ranawat et al. 1999 and Konyves et al. 2005), gait disorders (Rosler et al. 2000, Lai et al. 2001), suspected aseptic loosening (Amstutz et al. 1982, Visuri et al. 1993), and nerve palsy (Hofmann et al. 2000, Parvizi et al. 2003). However, the magnitude of a clinically significant LLD after THA is still controversial among authors. The association between LLD and GTP (secondary to increased tension of ITB over the greater trochanter and gait disturbance) was mentioned in the literature but not established (Shbeeb et al. 1996, Snider 1997, Alvarez-Nemegyei et al. 2004). Authors such as Iorio et al. (2006) suspected that LLD may play a role in occurrence of GTP but they found no such association in their material.

Surgeons are aware that restoration of the hip joint biomechanics with as normal leg length and femoral offset as possible is an important goal for a successful THA. Many techniques to measure LLD (and femoral offset) intraoperatively have been advocated and thoroughly discussed in the literature (Bal et al. 1996, Huddleston et al. 1997, Itokazu et al. 1997, Naito et al. 1999, Bose et al. 2000, Ranawat et al. 2001).
Aims of the studies

Study I

To estimate the incidence of GTP after THA, to evaluate the clinical outcome in GTP patients compared to controls and to determine associated factor(s).

Study II

To evaluate the PPT differences on palpation with an electronic algometer between subjects with GTP after THA and controls, i.e. the predictive validity of the algometer, to determine the ratio of side differences (affected vs. unaffected) in order to estimate the intra-individual cutoff value differentiating normal from pathological tenderness, to compare the PPT measurements on the greater trochanter (site of local pain) in relation to the upper part of ITB (site of referred pain), to correlate the PPT measurement to the intensity of the experienced pain represented by VAS, to assess the reproducibility of PPT algometric measurements for right and left body sides within asymptomatic subjects and to assess the value of a pressure algometer as a screening test by measuring its sensitivity, specificity and positive predictive value (PPV).

Study III

To evaluate the results of a new surgical procedure (Pedersen-Noor operation) proposed to treat refractory GTP after THA consisting of distal lengthening of ITB by Z-plasty.

Study IV

To investigate the degree of accuracy of a commonly used clinical method to measure LLD before and after THA by correlating it to a well-known and reliable radiological method.
Patients and Methods

Study I

One hundred and seventy-two consecutive patients underwent total hip arthroplasty at Sundsvall Hospital during January to December 2002. One hundred and fifty-eight patients underwent surgery for primary osteoarthritis and fourteen for secondary osteoarthritis. There were 106 women and 66 men with mean age of 69 years (30-91). The posterolateral approach (Moore incision) was used in all patients. The implant used was cemented Lubinus SPII stem and acetabular component which was either cemented Link cup (n=139) or non cemented Trilogy cup (n=33).

All patients received a questionnaire 11-23 months postoperatively to determine the presence of hip pain. A pain drawing was included to localize the site of the pain. The questionnaire included questions about the pain modalities, ADL and analgesics consumption. On walking (functional) VAS was used to determine the severity of the experienced pain (see Appendix). Eight patients were dropped out because they failed to return the questionnaire. Patients with suspected GTP (n=35) were compared with a group of asymptomatic patients selected from the same cohort. The control group (n=35) matched the GTP by age (2 years marginal) and sex. The two groups filled in Western Ontario and McMaster Universities (WOMAC) osteoarthritis index (Appendix) to assess the clinical outcome. WOMAC is a self-administered index of 0–100 (worst to best) validated for osteoarthritis in the lower extremities. It consists of 24 items grouped into three categories: pain (five questions), stiffness (two questions) and physical function (17 questions). This index is well validated by Bellamy (1985, 2005).

All patients (n=70) were subjected to physical examination at the outpatient department. Four patients from the suspected GTP group failed to show up at the follow up visit and were therefore dropped out from the study.
Tenderness over the greater trochanter and ITB was examined using a pressure algometer to measure the PPT bilaterally. Complete spinal and lower limb examination was performed in all patients. Leg length discrepancy was measured by two clinical methods: with a measuring tape with the patient in a standardised supine position of the distance between the ASIS and medial malleolus and with blocks increasing in thickness in increments of 0.5cm put under the shorter limb until the iliac crest appeared level. The mean of these measures was estimated as LLD. Femoral offset was measured on AP view of the postoperative radiographs as the distance between the midline and the longitudinal axis of the femoral shaft at the level of the greater trochanter on each side (Figure 3).

**Statistical analysis:** The student’s t test and chi-square test ($p<0.05$) were used to determine the significance of LLD and eventual correction of LLD with shoe lift in GTP and control group, WOMAC and VAS as well as algometer measurements. Multivariate logistic regression was used to assess whether there was a relationship between the lengthening of the operated limb and the body length that is associated with the GTP.
Figure 3: The radiological measurement of femoral offset was calculated as the distance between the midline and the longitudinal axis of the femoral shaft at the level of the greater trochanter on each side.

Study II

Patients included in study I with GTP and their controls (n=42) were examined using a pressure algometer (Somedic®, Sweden) to measure the PPT over the greater trochanter and ITB (junction of the upper 1/3 with the lower 2/3) bilaterally. To ensure that the measurement procedure was accurately understood, at least one trial PPT measurement was performed on the hand. The measurement was then obtained with the subject lying on the side with hip joints slightly flexed. The site of trochanteric tenderness was identified by gentle manual palpation. Linearly increasing perpendicular pressure was applied with the algometer, keeping
a ramp rate of 40-50 kPa/sec during application of pressure. The subject was told to press the hand-held button to record the PPT at the moment when the applied pressure felt as pain (Figure 4). All the measurements were performed by the same observer.

Three GTP patients (with their controls, total n=6) were excluded from study II because of difficulties encountered in standardizing the algometric measurements. Each of GTP and control groups consisted therefore of 15 females and 3 males (mean age 65 years, 45-82).

**Statistical analysis:** The student’s t test and Pearson correlation coefficient \((p<0.05)\) were used to assess the significance of PPT differences bilaterally and between the GTP and control group, as well as to determine the reproducibility of PPT measurement on the ITB bilaterally in the control group as this site can be considered as a non-affected area in an asymptomatic subject. To assess the value of pressure algometer as a screening test, the algometer sensitivity, specificity and PPV were measured. A 89% specificity and a 78% sensitivity values were used in accordance with the recommendation by Widmer et al. (1990) to determine PPT cutoff value and ratio over the trochanteric region in the GTP group. To evaluate the algometer’s value as a screening instrument we measured the PPV using GTP incidence of 12% (established in study I).
Figure 4: The method used to perform the PPT algometric measurements. The algometer is held perpendicular to the examined trochanteric region and a linearly pressure is applied under direct visual control of the pressure ramp shown at the electronic display of the device.

Study III

Twelve patients with refractory GTP after THA underwent surgery at Sundsvall Hospital between March 2004 and June 2006 using a novel surgical procedure consisting of distal lengthening of ITB by Z-plasty. The criteria of diagnosing GTP included aching and tenderness over the greater trochanter with or without radiation along the ITB, with exacerbation on hip rotation and abduction against resistance. Patients with atypical signs and symptoms were investigated with radiographs to exclude any abnormalities concerning the prosthesis. Before being considered for the operative treatment, all patients underwent at least 6 months of conservative treatment with NSAIDs, physiotherapy and local corticosteroid without sustained improvement.

The mean age at the time of surgery was 68 years (47-84) and the mean interval between
THA and the lengthening operation was 37 months (12-105).

Leg length discrepancy in these patients was measured on the THA postoperative radiographs as the distance between a horizontal line passing through the tear-drop points bilaterally, and the tip of lesser trochanter on each side.

**Surgical technique:**

No antibiotic prophylaxis was given. The operations were performed in the operating theatre with the patient in lateral decubitus position. The skin and subcutaneous tissue were infiltrated with 15 to 30 millilitres of 1 % Xylocaine with adrenalin above the lower third of the ITB. A ten centimetre incision was made in the skin and subcutaneous tissue over the central part of the ITB. Three parallel incisions of about seven to eight centimetres were made in the ITB. The outer two incisions were made where the ITB margins meet the muscle fibres anteriorly and posteriorly while the third incision split the ITB in the middle. The Z-plasty was completed by two transverse incisions and usually gave a lengthening of the ITB of about 1.5-2 cm (Figure 5). The incisions in the ITB were sutured with interrupted absorbable Vicryl®. The subcutaneous layer was then closed with Vicryl® as required and the skin was closed either with metal clips, Ethilon® suture or subcutical Monocryl®. Postoperatively, the patient was mobilized freely and no specific physiotherapy was described.

Postoperative follow up was performed by phone interview three to four months after the operation. All patients had completed the EQ-5D questionnaire (Appendix) for health status (including a 0-100 scale of the present health quality) before the operation and 11-37 months (mean 28) postoperatively. Shortly after we received the postoperative EQ-5D, the patients were further evaluated through clinical examination. Two patients were dropped from the study as they did not want to come to the clinical examination. The clinical examination included history-taking regarding the direct postoperative period, including the wound healing and the onset of any improvement or worsening of GTP. The physical examination included
evaluating bilateral hip and knee ROM, muscle strength and stability as well as palpation of
the greater trochanter, ITB and operation site. Furthermore, residual tenderness over the
greater trochanter was evaluated in seven patients using a pressure algometer (Somedic®).

**Statistical analysis:** the Wilcoxon rank-sum test and the student’s t test were used \( p<0.05 \)
to determine the difference between EQ-5D index before and after the operation.

**Figure 5:** Three parallel incisions made in the ITB. Two incisions are made where
the ITB meets the muscles at the periphery and the third is in the middle of it. The Z plasty
results in lengthening of the ITB by 1.5-2 cm.
Study IV

To compare LLD measurement before and after THA, 139 patients with osteoarthritis of the hip were studied at the Karolinska University Hospital during the period September 2002 to March 2005. There were 85 females and 54 males with ages ranging from 44 to 89 (mean 67.5 years). Two to three weeks before the operation, patients were examined by the same physiotherapist who measured LLD bilaterally, using a measuring tape, as the distance between the ASIS and the medial malleolus with the patient in a supine position. During examination both legs were placed in neutral position and close to each other to make measurement as standardized as possible. Furthermore, patients were examined preoperatively using plain radiographs of the pelvis and hip joints. These radiographs were standardized by holding the lower limbs together in a neutral position while taking the pictures. On the AP view of the pelvis, the LLD was measured by the same radiologist for all cases, as the perpendicular distance between a line passing through both tear drops medial to the acetabulae to the corresponding tip of the lesser trochanter. A radio-opaque ruler was used for accurate calibration of the picture scale (Figure 6). A positive LLD value was used when the operated limb was longer than the contralateral side while a negative value indicates the opposite. All patients were then operated using the lateral approach (Modified Hardinge 1982). On the third postoperative day, LLD was again measured clinically and radiologically by the same physiotherapist and radiologist using the same method of measurement as preoperatively. The physiotherapist was blinded to the measurements of the radiologist and vice versa. In all of the clinical measurements we used a 5mm precision scale while the radiological measurements had a 1mm precision scale.

Statistical analysis: To investigate the degree of correlation between the clinical and radiological measurements before and after THA, we used the Pearson’s correlation and ICC.
We measured the degree of difference between the mean values of these measurements with paired sample test ($p < 0.05$ was considered as significant).

**Figure 6:** The method used to measure LLD on radiographs. The distance between a horizontal line passing through the tear drop points bilaterally to a constant point on the tip of the corresponding lesser trochanter is measured on each side, and LLD is calculated as the difference. As it is apparent in this figure, pelvic tilt is a common manifestation in these patients and using fixed points such as the tear-drop points will minimize the bias encountered in LLD measurements.

**Ethical considerations:**

All studies were conducted in accordance with the Helsinki Declaration and each protocol was approved by the regional ethical committee.
Results

Study I

The evaluation of patients with suspected GTP showed that 21 patients (12%) had clinical manifestations of this condition. There were 18 females (86%) and 3 males (14%), with a mean age of 66 years (43-83). The severity of GTP was variable. Ten patients (5.8%) had complaints that affected their ADL, and they needed treatment on daily basis.

Lengthening of the operated leg by 1 cm or more was found in 19/21 patients (90%) in the GTP group (mean of LLD 1.3 cm) while in controls only 8/21 (38%) had lengthening of the operated limb of one centimetre or more (significant difference between groups; $p<0.0002$). The remaining controls either had no leg length discrepancy or less than one centimetre (mean LLD 0.5 cm),

In the GTP group, only two patients had corrected the lengthening with a shoe or heel rise on the opposite side. Others (17 patients) had not corrected the lengthening because they had not been counselled about it or they used the rise only intermittently. On the other hand, six of the eight in the control group had corrected LLD with a shoe lift early after the operation and continued to use it regularly, which is different from the GTP group ($\chi^2 <0.0009$).

The WOMAC index in the GTP group revealed a significant reduction of the outcome of the THA operation (mean 67% vs. 88% in controls; $p<0.0001$). Moreover, the mean of algometer measurements in the GTP group was 69% (i.e. 69% of the pressure applied on the normal side was needed to reproduce the pain on the affected side) vs. 98% in controls which was significantly different; $p<0.0001$. These results are summarised in Figure 7.

We could not find any correlation between the change of femoral offset and the occurrence of GTP. There were no difference of the femoral offset in the affected hip compared to the contralateral side in the GTP group compared to less than 3% difference in controls.
Furthermore, no correlation was found between the occurrence of GTP and the sizes of the prosthetic components used, patients’ weight or body length.

No statistical relation was found between the lengthening of the operated limb associated with the GTP and the body length.

Figure 7: Summary of the patients included in study I, with their results.

Study II

The PPT algometric measurements over the affected greater trochanter (mean 382 kPa, SD 195kPa) and ITB (mean 563 kPa, SD 286 kPa) in the GTP group were significantly lower than the equivalent values over the contra-lateral side (greater trochanter mean 624 kPa, SD 305 kPa and ITB mean 680 kPa, SD 350 kPa) \( (r=0.68, p=0.002 \text{ and } r=0.90, p=0.0001 \) respectively). No such a difference could be found in the control group: greater trochanter
(mean 750 kPa, SD 176 kPa) and ITB (mean 693 kPa, SD 211 kPa) on the operated side with the contra-lateral side (greater trochanter mean 775 kPa, SD 135 kPa and ITB mean 685 kPa, SD 192 kPa) \((p=0.453\) and \(p=0.760\) respectively), i.e. good “predictive” validity (Figure 8).

Furthermore, the PPT measurements over the greater trochanter (site of local pain) on the affected side in GTP group were significantly lower than the measurements obtained over the ITB (site of radiated pain) on the same side \((r=0.60, p=0.01)\).

There was good reproducibility (correspondence) of PPT measurements when comparing data for right and left body sides on ITB \((r=0.87, p=0.001)\) respectively. The mean ratio of algometric PPT measurements over the trochanteric region (affected/unaffected side) was 0.65 (SD +/- 0.23). This was significantly different from the mean ratio of 0.97 (SD +/- 0.17) obtained over the trochanteric region in the control group, \(p<0.001\).

The proper intra-individual cutoff value differentiating normal from pathological tenderness i.e. the ratio of PPT measurements of the affected to the unaffected side was found to be 0.8.

VAS index was significantly higher \((p=0.0001)\) in the GTP group (mean 3.9, range 1-7) than in the control group (mean 0.74, range 0-2). We found no correlation between VAS index and PPT algometric measurements.

Values of 89% specificity and a 78% sensitivity were used to determine PPT cut-off values over the trochanteric region in the GTP group. These values corresponded to a cut-off value of 636.5 kPa. In the present study there were 16/18 GTP patients who showed PPT values of less than the given cut-off value, vs. 4/18 in controls.

Using the above mentioned specificity and sensitivity values as well as the estimated prevalence of 12%, the positive predictive value of the algometer as screening instrument was calculated to be 50%.
**Study III**

The EQ-5D index showed an improvement in all but one patient who experienced no change in the GTP complaint after the operation. The mean of EQ-5D index was 0.26 (0-0.73) before the operation and 0.67 (0.16-1.0) after the operation ($p <0.005$). The mean health quality index was 34 +/- 10 (range 10-60) before the operation and 60 +/-20 (range 30-90) after the operation ($p <0.005$).

On post-THA radiographs all patients except one had a lengthening of the operated leg, with a mean increase of leg length of 0.85 cm +/- 0.43 (0-1.5 cm).

The phone interviews performed three to four months after the operation revealed that seven patients experienced improvement of the GTP signs and symptoms. Four patients reported a gradual improvement on later follow up. One of those four patients felt neither improvement nor deterioration in her GTP complaint, but the tightness and tenderness along ITB that she had developed after the THA operation disappeared after the Z-plasty operation with...
subsequent improvement of hip and thigh ROM. The remaining patient showed neither improvement nor deterioration in her GTP complaint or EQ-5D index. Clinical examination 1-3 years postoperatively revealed no signs of decreased ROM, decreased strength or instability of the ipsilateral hip or knee. The algometric PPT measurements performed in seven patients revealed a mean value of 357 kPa over the affected greater trochanter vs. 427 kPa over the contralateral greater trochanter i.e. cutoff ratio of 0.84. No postoperative complications were encountered after the Z-plasty.

Study IV

The mean of preoperative clinical LLD measurements was -1 mm (S.D. = 9 mm) while the mean of preoperative radiological LLD measurements was -5 mm (S.D. = 7 mm). There was a weak correlation/agreement between these two measurement methods (correlation r =0.21, intra-class correlation coefficient ICC =0.33) and the estimated LLD as evaluated by clinical and radiological methods where significantly different (p<0.0001).

Postoperative clinical LLD measurement showed a mean of 2 mm (S.D. = 7 mm) while postoperative radiological LLD measurement showed a mean of 3 mm (S.D. = 7 mm). The correlation / agreement between these measures was fair (r=0.45, ICC=0.62). There was no significant difference between the means of the postoperative clinical and radiological measures (p<0.177).
Discussion

Greater trochanteric pain after THA is not a rare complication. The incidence found in study I (12%) was higher than the incidence found by others (Vicar et al. 1984, McAuley et al. 1998, Schinsky et al. 2003, Iorio et al. 2006). This discrepancy is probably related to the different GTP selection criteria used in these studies. In our study, for example, we actively searched for patients with signs and symptoms of GTP, including all the patients regardless of the severity of their complaints. There were 10 patients (5.8%) who had been in contact with their surgeons because of the GTP complaints. Others had sporadic visits to a GP or self-medicated. However, the overall outcome of THA in the GTP group measured by WOMAC index was lower than in controls. Similar reduction in outcome was found by Iorio et al. (2006).

The high incidence of GTP after transtrochanteric approach is probably due to the direct trauma applied on the gluteal muscle attachments on the greater trochanter with their surrounding bursae. Furthermore, the metalware used to fix the osteotomy may irritate the soft tissues surrounding it, giving rise to pain and tenderness. On the other hand, THA using anterolateral approach (Hardinge) involves the detachment and re-attachment of up to two thirds of the gluteus medius muscle attachment to the greater trochanter.

Consistent with other studies (Iorio et al. 2006, Segal et al. 2007), the incidence of GTP in our study was more common in females (female to male ratio was 6:1). The mechanism of this increment is still unclear. Possible explanations include hormonal influence on the bursae, differences in pelvic anatomy with increased ITB tension, differences in pain perception and differences in physical activity.

The association found in study I between lengthening of the operated limb by ≥1 cm and the occurrence of GTP is an interesting finding. In patients with OA changes of the hip, there is often a shortening of the affected limb with soft tissue contracture apart from the degenerative
changes. When operating on such patients, restoration of leg length and femoral offset might
give rise to increased tension on the lateral aspect of the hip. The authors believe that
lengthening of the operated limb resulted in an increased traction of ITB on the greater
trochanter. Furthermore, the gait disturbance caused by the lengthening loads the gluteal
muscle attachment to the greater trochanter. The violation caused by the surgical trauma of
THA adds an extra factor and this might minimize the degree of LLD needed to predispose to
GTP occurrence.

The early correction of LLD with a shoe lift under the short limb found in the control group
might have reduced some of the traction and the biomechanical disturbance caused by LLD
and therefore can possibly reduce the risk of its GTP occurrence. However, the material
involved in this correction is small and probably non-conclusive.

We tried to improve the accuracy of LLD measurements by using 2 clinical methods (ASIS-
medial malleolus and blocks). We took the average values and all measurements were done
by the same observer and in a standardized manner to minimize the risk of bias. We preferred
not to measure LLD on radiographs because of the lack of standardization in patients’
radiographs.

Despite our expectations, we found no correlation between GTP occurrence and femoral
offset. The method of offset measurement we used is well known in the literature, but we are
unaware of whether it is validated. All the radiographic measurements of femoral offset were
done by one observer which may have reduced bias. Similarly to our study, Iorio et al. (2006)
found no correlation between femoral offset and GTP.

No statistical correlation was found between the occurrence of GTP and body weight and
length, the degree of limb lengthening to body length and the thickness or angle of neck of the
femoral component used.
We believe that the use of a pressure algometer in study II made the assessment of trochanteric tenderness associated with GTP more objective. When eliciting tenderness, at least two aspects will be involved: a decreased PPT and an increased response to the given stimulus. These two aspects can vary, giving rise to a variable severity. Due to this variability, the method used for evaluation of tenderness should be reliable. Finger palpation (the most commonly used method) exerting an excessive pressure over a giving area can give a false positive result in a healthy individual and vice versa. Furthermore, different observers using various palpation techniques can evaluate the degree of tenderness (and subsequently the severity of the given condition) in different ways. The follow up of such tenderness with finger palpation is another problem.

In this study, the use of an algometer on the hip showed good predictive validity, which means that this instrument was able to predict something it should theoretically be able to predict, in this case the GTP patients to have lower PPT than controls. This is consistent with other studies which investigated the algometer validity and intra-observer and inter-observer reliability on other parts of the body (Fischer 1987, Ohrbach et al. 1989, Chung et al. 1993, Naussbaum et al. 1998, Farella et al. 2000, Silva et al. 2005). Furthermore, these studies showed that the algometer was useful for measuring PPT in both symptomatic and symptom-free individuals for diagnostic purposes, and for the evaluation of the efficacy of different treatment strategies, mainly in orofacial practice. The instrument allows the patient to self-actuate the cutoff point through a hand-held button. The latter character is thought to reduce a potential operator error factor (Chung et al. 1993).

We chose to make all PPT measurements by the same examiner and the rate of algometric pressure application was kept constant in this study (40-50 kPa/sec) to ensure good reliability of the algometer (Chung et al. 1993, Nussbaum et al.1998).
We examined the painful side first because we believed that lying on the painful side first might evoke pain with subsequent local and central sensitisation leading to a possible bias in measuring the PPT on this side later on.

The detection of increased PPT over ITB (site of radiated pain) in relation to the greater trochanter itself (site of local pain) is an issue of interest. A similar phenomenon has been found by other researchers (Kosek et al. 1993 and 1999, Abou Atme et al. 2005). In addition to the fact that the pathological changes in GTP are localized at the trochanteric region and not at the ITB, this discrepancy might also due to the differences in the thickness of subcutaneous tissue of these two sites (Kosek et al. 1993, 1999). Another possible explanation is what is called diffuse noxious inhibitory control (DNIC). In muscle pain patients, it is believed that a pathologically disturbed inhibitory mechanism may result in widespread deep hypoalgesia of the surrounding tissues (Abou Atme et al. 2005).

The absence of a significant correlation between PPT algometric measurements and VAS in the present study indicates the complexity of using VAS as a simple pain evaluator. It also reveals the fact that different factors (including psychological) play a role in the experience of pain in addition to the local (nociceptive) factor. Poor correlation was also found by Walco et al. (1990) while others e.g. List et al. (1993) and Hogeweg et al. (1992), by contrast found a significant correlation between PPT and VAS. This discrepancy could be due to the differences in measurement sites of PPT, as well as the pathology of the condition investigated in different studies.

The large inter-individual variability of PPT measurements across subjects found in study II was previously documented by other investigators (Jensen et al. 1986, Tunks et al. 1988, Vantin et al. 1998, Persson et al. 2004, Rolke et al. 2005). Indeed, these findings reflect the importance of intra-individual side to side comparisons of PPT measurements when assessing deep pain sensitivity.
The large inter-individual variability together with the relatively low PPV found in this study (50%) and by other authors such as Farella et al. (2000) suggest that the pressure algometer might have limited value as a screening instrument when used to compare PPT measurements among subjects in case of GTP screening for example following THA.

On the other hand, the study shows good reproducibility (correspondence) of the algometer in measuring PPT when used on the ITB of the control group. The 0.8 ratio of PPT algometric measurements of the affected to the unaffected side found in the present study can be used for diagnostic purposes, to differentiate normal from pathological tenderness in patients with suspected GTP. This value was very close to the value of 84.1% found by Fisher 1987. There were six GTP patients with a PPT ratio > 0.8 overlapping the PPT ratio of the control group. Five of these patients had a mild degree of GTP with good response to NSAIDs. One patient had a bilateral GTP complaint with decreased PPT on both sides.

The selection of a cutoff value corresponding to 78% sensitivity and 89% specificity is recommended by different studies. According to Widmer et al. (1990), when the condition investigated is of low mortality (as in GTP), the sensitivity and specificity levels of diagnostic tests performed in medical sciences should be around 75% and 90%, respectively. These values allow the test to diagnose about 25% of would-be patients as healthy and 10% of healthy individuals as patients.

Researchers have used a pressure algometer to assess the effect of different treatment modalities such as intra-muscular injections (Fischer 1984, Jensen et al. 1986, Christidis et al. 2007) and physiotherapy (including acupuncture) (Fischer 1984, List et al. 1993) on the PPT. The good validity of the algometer shown in study II and the determined ratio indicate the potential use of this instrument to evaluate the effect of different types of GTP treatment on the PPT in a more reliable way compared to finger palpation or VAS index.
The treatment of GTP after THA is mainly conservative and Iorio et al 2006 reported good response to measures such as corticosteroid injections, physiotherapy with or without ultrasound, NSAIDs or merely observation of all GTP cases studied (n=24). However, in our experience some patients need surgical intervention since GTP complaints can be refractory and adversely affect their physical ability.

Many investigators reported good results of different surgical methods used in the treatment of refractory trochanteric bursitis or painful snapping hips. These methods relied on the same principle of minimizing the pressure or friction applied on the greater trochanter by the tense/thickened ITB. On the other hand, we are unaware of any studies investigating surgical treatment of refractory GTP after THA.

Brignall et al. (1991), Lam et al. (2003) and Provencher et al. (2004) used a local proximal Z-plasty to release the ITB over the greater trochanter in patients with painful snapping hip. These patients showed favourable response and the method was recommended as an alternative to the conservative therapy in refractory cases.

The same method was used by Kim et al. (2002) who treated three military patients with painful snapping hip. The results of this study were less than optimal.

Brooker (1979) reported good response to T- incision or local fenestration of ITB with removal of trochanteric osteophytes and debridement of the gluteal maximus bursa. The method was performed in five patients with one year follow up. These patients showed improvement of mean Harris hip score from 46 to 88 after the operation.

Zoltan et al. (1986) described a surgical method of elliptical incision of ITB creating a defect over the greater trochanter followed by trochanteric bursectomy in seven active patients who developed refractory trochanteric pain secondary to snapping hip. The average length of follow up of these patients was 55 months. One patient was operated on twice. All patients showed good response.
Slawski et al. (1997) reported a single surgeon’s experience of treating seven hips by simple longitudinal release of the ITB over the greater trochanter with excision of the subgluteal bursa. The mean follow up of this study was 20 months and these patients responded well to this surgical treatment with obvious improvement of Harris hip score (mean 51.7 to 95.0).

Govaert et al. (2003) described a new operative procedure consisted of trochanteric reduction osteotomy with screw fixation. Ten patients (12 hips) were operated in this series. The mean follow up was 23.5 months. The mean Merle d’ Aubigné and Postel score improved from 15.8 to 27.5. The method was considered as safe and effective. The authors of this work reported previous poor response to longitudinal release of the ITB with trochanteric bursectomy which had been performed on five hips.

Arthroscopic treatment of refractory GTP and snapping hip was performed by Fox (2002) and Ilizaliturri et al. (2006). In the former work, twenty-seven hips with refractory GTP were treated with arthroscopic bursectomy and the patients were followed up one and five years after the operation. Only two patients showed manifestations of recurrence, otherwise all other patients had good to excellent results. However, it was not clear how the results were evaluated, because a specific outcome index had not been used. In the later work, eleven snapping hips were operated with arthroscopic release of ITB. Two-year follow up of these patients revealed non-painful snapping in one patient while the rest of the patients had no complaints and had returned to their previous level of activities. The WOMAC was used in this series.

Chirputkar et al (2007) reviewed the results of a series of 16 patients treated with bursectomy and Z-lengthening of the ilio-tibial band over the greater trochanter. The mean follow up was 52 months. The authors used a questionnaire to evaluate the pain and degree of satisfaction in the operated patients and found that all 14 patients who answered the questionnaire were
happy with the outcome of operation and 13/14 patients would undergo a similar procedure again. However, it is not clear whether the questionnaire used was a validated one or not.

We believe that treating patients with refractory GTP after THA with local ITB release with or without bursectomy gives poor results, and applies further trauma to the area already injured by the THA operation. This may increase the risk of wound infection and recurrence of GTP. On the other hand, technical difficulties may be encountered if GTP patients undergo arthroscopic surgery. Trochanteric reduction osteotomy (Govaert et al. 2003) can not be performed due to the presence of hip prosthesis.

The distal ITB lengthening by Z-plasty as described in study III was first performed by Eskild Pedersen MD at Sundsvall Hospital in 1997. The idea behind this procedure was taken from the lengthening of extensor carpi radialis brevis (ECRB) muscle tendon in the treatment of refractory tennis elbow (Stovell et al. 1979, Kumar et al. 2004) without applying further trauma locally at the site of pain. Fridén et al (1994) found that lengthening of the ECRB by 9.1 mm resulted in a 25% decrease in passive muscle tension that could lead to reduced tension and decreased pain.

In study III we had no control group. However, the patients included had experienced their GTP complaints for at least 12 months before they underwent the lengthening operation described. The algometric cutoff ratio of 0.84 estimated in the operated patients of study III supports our finding in study II, which showed asymptomatic patients of the control group had a cutoff ratio of more than 0.80.

The technique described is simple, safe and effective. It is performed under local anaesthesia and on an outpatient basis. The follow up results and the absence of postoperative complications in this study encourage the authors to recommend this method for the treatment of refractory GTP after THA. It should be emphasized that patient selection is crucial. In a patient with disabling refractory GTP and increased tightness of ITB, distal Z-plasty
represents a promising therapeutic alternative. However, a prospective larger study of this technique for the treatment of GTP after THA is recommended for further evaluation.

Lengthening of the operated limb after THA has been described as a possible cause of GTP development. In study IV we found shortening of the affected limb preoperatively. This is a common finding and is usually secondary to loss of hip joint space with or without cranial migration of the femoral head as well as soft tissue involvement with adduction/abduction and flexion contractures of the affected hip. Postoperatively, on the other hand, there was a lengthening of the operated leg. This is also a common outcome after THA because many surgeons tend to lengthen the operated leg as they try to achieve good stability around the operated prosthesis. This phenomenon was also described by Ranawat and Rodriguez (2001).

The weak correlation between the clinical and radiological measurements preoperatively is probably due to the fact that the radiological measurement was more accurate and easily standardized than clinical examination. The shortening was less apparent clinically than radiologically because of the painful contracture in the affected hip with a compensating pelvic tilt/obliquity that minimized the apparent shortening. The correlation between the clinical and radiological measurement was better postoperatively. The authors believe this was the result of the THA which minimized soft tissue contracture allowing the patient to lie on the examination table with less pain. This made the clinical measurement of LLD more accurate and correlated better with the radiological examination. Clinicians should therefore be aware of the limitations encountered in the use of the described clinical method for the evaluation of preoperative LLD in patients considered for THA. Furthermore, caution is advised in using the clinical method of postoperative LLD measurement despite its better correlation with the radiological measurement. In cases were LLD measurement can give rise to further intervention such as revision surgery the authors recommend the use of a well-documented method with a high degree of precision such as CT scanogram.
Summary and Conclusions

Despite the incidence of GTP after THA having become lower since the posterior and the lateral approaches successively replaced the transtrochanteric approach, this complication represents a drawback in the outcome of an otherwise a very successful procedure. We found an incidence of 12% with decreased clinical outcome determined by WOMAC index (Study I).

Lengthening of the operated limb by $\geq 1$cm was found to be an associated factor (study I). Every effort should therefore be taken to minimize the risk of LLD after THA. This is usually achieved by preoperative templating and intraoperative leg length measurement. We recommend the use of the radiological method of LLD measurement both before and after THA (study IV). The use of a pressure algometer can be promising in the diagnosis and follow up of the effect of treatment. We found that the used algometer had good predictive validity and reproducibility. The cutoff ratio of 0.8 can be used to differentiate pathological from normal tenderness. There were considerable inter-individual differences in PPT measurements, and the algometer PPV was found to be 50%. This makes the use of the algometer unsuitable as a screening instrument. Fortunately most of GTP patients respond to non-operative measures. For those who show refractory GTP manifestations, distal lengthening of ITB band is a simple, safe and effective procedure.
**Future implications**

1) It is of a great interest to evaluate the incidence and associated factors of GTP after minimal invasive surgery (MIS) especially when the anterior approach is used. Furthermore, the use of navigation systems in hip replacement surgery can affect the incidence of postoperative LLD.

2) The effect of lengthening the operated limb and the early correction of LLD can be investigated using a prospective controlled trial where correction of LLD is randomized against non-correction to study its role.

3) Distal lengthening of the ITB band can be used in non-THA operated GTP patients. Randomisation of patients with refractory GTP complaints between the distal lengthening of ITB against proximal ITB decompression/fenestration or continued conservative therapy is necessary to evaluate the actual effect of these different modalities.
**Populärvetenskaplig sammanfattning**

I Sverige opereras över 14.000 patienter årligen med höftprotes och det är en av de mest framgångsrika och kostnadseffektiva operationerna överhuvudtaget. Emellertid blir 5-15 % av patienter inte nöjda med resultatet av operationen då de utvecklar ett smårtillstånd över höftens utsida som brukar kallas trokanterit eller greater trochanteric pain (GTP). Målsättning med avhandlingen var att undersöka förekomsten av GTP, att studera eventuella riskfaktorer, att bedöma livskvalité hos drabbade patienter jämfört med en kontrollgrupp, att mäta graden av tryckömhet över höften med en tryckmätare (algometer), att jämföra två metoder för mätning av benlängdsskillnad hos höftprotesopererade patienter och att evaluera resultatet av en ny kirurgisk teknik för behandling av GTP smärta.

**Studie I:** Bland 172 patienter som opererades år 2002 på Sundsvalls sjukhus med höftprotes förekom GTP besvär med varierande svårighetsgrad hos 12 %. Livskvalité bedömd med WOMAC index var nedsatt hos dessa patienter jämfört med en ålders- och könsmatchad kontrollgrupp. GTP var vanligare hos kvinnor och hos patienter där det opererade benet förlängts > 1cm. Tidig korrektion av benförlängning med skoinlägg minskade risken för GTP.

**Studie II:** Med en elektronisk mätare (algometer, Somedic®, Hörby-Sverige) undersöktes tryckömheten över höften (trokanter) och lårets utsida (traktus ilio-tibialis). Hos 18 patienter med GTP efter höftprotesoperation och en matchande kontrollgrupp undersöktes algometerns prediktiva validitet, cutoff värde och kvot för att särskilja den patologiska från den normala ömheten, specificitet och sensitivitet samt positiva prediktiva värdet (PPV) för att bedöma algometerns värde som instrument för diagnostik och screening. Vi fann att algometermetoden har en god prediktiv validitet. Vid den rekommenderade sensitiviteten av 75% och specificiteten av 90% fann vi ett cutoff värde på 636,5 kPa samt en cutoff kvot på 0,8. Detta innebär att algometer kan användas för att diagnosticera GTP hos patienter med höftvärk. Apparaten kan även användas för evaluering av olika behandlingsmetoders resultat. Eftersom
det förelåg stora individuella skillnader i tryckömhet bland patienter och i kontrollgruppen och då PPV var endast 50% bedömde vi att algometer inte är lämplig som screeningsinstrument.

**Studie III:** Vi studerade resultatet av en ny kirurgisk metod för att behandla resistenta GTP besvär efter höftprotesoperation. Metoden syftar till att förlänga traktus iliotibialis med Z-plastik i nedre delen av läret ca 10 cm ovanför knäleden. Operationen görs i lokalbedövning och patienten går hem samma dag utan restriktioner. Mellan mars 2004 och juni 2006 opererades 12 kvinnor (medelålder 68, 47-84 år) enligt den nya metoden. Inga patienter rapporterade någon komplikation. Utvärdering gjordes med klinisk undersökning och EQ-5D hälsoenkät före och 1-3 år efter operationen och på röntgenbilder uppmättes benlängdsskillnad. Vi fann att hos 11 av 12 opererade patienter minskade GTP besvären och förbättrades livskvalitén [EQ-5D index före operationen var 0-0.73 (medelvärde 0.29) medan efter operationen var 0.16 – 1.0 (medelvärde 0.70)].

**Studie IV:** Hos 139 patienter med höftartros som opererades med höftprotes på Karolinska Universitetssjukhuset, Solna perioden mellan sep 2002 till mars 2005 uppmättes benlängdsskillnad kliniskt och röntgenologiskt före och efter operationen. Vid den kliniska bedömningen av benlängdsskillnad uppmättes på båda sidor avståndet mellan en specifik punkt i bäckenet (spina iliaca) och inre fotknölen (mediala malleolen) med patienten i liggande ställning. Den röntgenologiska benlängdsskillnaden bestämdes till skillnaden i det vinkelräta avståndet mellan linjen genom tear-drop punkterna i bäckenet och spetsarna på trokanter minor på lårbenen.

Vi fann en svag korrelation mellan kliniska och röntgenologiska benlängdsmätningarna före operationen. Efter operationen var korrelationen måttlig mellan mätningarna. Utifrån vårt resultat föreslås att benlängdsmätning före operationen bör göras röntgenologiskt då en klinisk mätning underskattar benförkortningen.
References

A


B


Bird PA, Oakley SP, Shnier R, Kirkham BW. Prospective evaluation of magnetic resonance imaging and physical examination findings in patients with greater trochanteric pain syndrome. Arthritis Rheumat 2001; 44: 2138-45.


C


D


Fisher AA. Diagnosis and management of chronic pain in physical medicine and rehabilitation. Curr Ther Psychiatry 1984; 8:123–145.


M


N


O


P


T


V


W


Z
Appendix

Ortopedkliniken
Sundsvalls sjukhus

Enkät om kvarstående värk efter höftprotesoperation

Namn: __________________________ Personnummer: __________________________

Opererad höft ( ), höger O vänster

1. Har du värk i den opererade höften på natten?

   A) Jag har ingen värk i höften på natten
   B) mättig värk
   C) svår värk
   D) mycket svår värk

2. Har du värk i höften då du ligger på sidan på den opererade höften?

   A) Jag har ingen värk då jag ligger på den opererade höften
   B) mättig värk
   C) svår värk
   D) mycket svår värk

3. Har du smärtor på utsidan av den opererade höften då du reser dig upp ur en stol?

   A) Jag har ingen smärtor på utsidan av höften då jag reser mig upp ur en stol
   B) mättig smärtor
   C) svår smärtor
   D) mycket svår smärtor

4. Hur lång sträcka kan du gå innan eventuell smärtor i höften stoppar dig?

   A) Jag kan promenera mer än en kilometer utan smärtor
   B) 500 – 1000 meter och begränsas sedan av smärtor
   C) 50 – 500 meter och begränsas sedan av smärtor
   D) mindre än 50 meter

5. Kan du stå på ett ben på den opererade sidan?

   A) Jag kan stå på det opererade benet utan stöd och utan smärtor
   B) kan stå med stöd och utan smärtor
   C) kan stå med smärtor
   D) kan inte stå på ett ben

6. Behöver du ta värktäkter för att lindra värken och smärtor i höften?

   A) Jag åter inga värktäkter
   B) några gånger i månaden
   C) varje vecka
   D) varje dag

031109 Anna Berggren, med kand
7. Använder du någon form av gånghjälpmedel?
   A) jag använder inte gånghjälpmedel
   B) käppkrycka
   C) rollator
   D) gånbord eller annat gånghjälpmedel: __________________________

8. Om du har vård eller smärta i den opererade höften, markera på linjerna nedan hur du upplever din vård och smärta:

   Vård i vila (Rita ett kryss på linjen)
   __________ X ____________
   ingen vård   lätt vård   mättlig vård   svår vård   outhårdlig vård

   Smärta vid aktivitet (Rita ett kryss på linjen)
   __________ X ____________
   ingen vård   lätt vård   mättlig vård   svår vård   outhårdlig vård

WOMAC Höft Index

Datum____________________
Personnummer_____________
Namn____________________

Smärta:
Följande frågor rör den höftsmärta du eventuellt upplevt den senaste veckan. Ange graden av smärta du har känt i följande situationer:

1) Gå på jämnt underlag
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   ◘ ◘ ◘ ◘ ◘

2) Gå upp eller ner för trappor
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   ◘ ◘ ◘ ◘ ◘

3) Under natten i sängläge (smärta som stör sömnen)
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   ◘ ◘ ◘ ◘ ◘

4) Sittand eller liggande
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   ◘ ◘ ◘ ◘ ◘

5) Stående
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   ◘ ◘ ◘ ◘ ◘

Stelhet:
Följande frågor rör ledstelhet (inte smärta). Stelhet innebär svårighet all komma igång eller ökat motstånd vid rörelser i höftleden. Ange graden av stelhet du upplevt i din höft den senaste veckan:

1) Hur stel har din höft varit när du just har vaknat på morgonen?
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   ◘ ◘ ◘ ◘ ◘

2) Hur stel har din höft varit efter att du suttit eller legat och vilat senare under dagen?
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   ◘ ◘ ◘ ◘ ◘

Fysisk funktion:
Följande frågor rör din fysiska funktion. Ange graden av svårighet du har upplevt den senaste veckan vid följande aktiviteter på grund av dina höftbesvär

1) Gå nerför trappor
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   ◘ ◘ ◘ ◘ ◘

2) Gå uppför trappor
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   ◘ ◘ ◘ ◘ ◘

3) Resa upp dig från sittande
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   ◘ ◘ ◘ ◘ ◘

4) Stå stilla
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   ◘ ◘ ◘ ◘ ◘

5) Böja dig, t ex för att plocka upp ett föremål från golvet
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   ◘ ◘ ◘ ◘ ◘

6) Gå på jämnt underlag
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   ◘ ◘ ◘ ◘ ◘
7) Stiga i och ur bil
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   □ □ □ □ □
8) Handla/göra inköp
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   □ □ □ □ □
9) Ta på strumpor
   Ingen     Lätt     Måttlig     Svår     Mycket svår
   □ □ □ □ □
10) Stiga ur sängen
    Ingen     Lätt     Måttlig     Svår     Mycket svår
     □ □ □ □ □
11) Ta av strumpor
    Ingen     Lätt     Måttlig     Svår     Mycket svår
    □ □ □ □ □
12) Ligga i sängen (vända dig, hålla höften i samma läge under lång tid)
    Ingen     Lätt     Måttlig     Svår     Mycket svår
    □ □ □ □ □
13) Stiga i och ur badkar/dusch
    Ingen     Lätt     Måttlig     Svår     Mycket svår
    □ □ □ □ □
14) Sitta
    Ingen     Lätt     Måttlig     Svår     Mycket svår
    □ □ □ □ □
15) Sätta dig och resa dig från toalettstol
    Ingen     Lätt     Måttlig     Svår     Mycket svår
    □ □ □ □ □
16) Utföra tungt hushållsarbete (snöskottning, golvtvätt, dammsugning etc)
    Ingen     Lätt     Måttlig     Svår     Mycket svår
    □ □ □ □ □
17) Utföra lätt hushållsarbete arbete (matlagning, damning etc)
    Ingen     Lätt     Måttlig     Svår     Mycket svår
    □ □ □ □ □

Tack för att du tagit dig tid att besvara samtliga frågor!

**EQ-5D Hälsoenkät**

Namn: ______________
Personnummer: __________
Datum: ______________

Markera genom att kryssa i en ruta i varje nedanstående grupp vilket påstående som bäst beskriver Ditt hälsotillstånd idag:

**Rörlighet**
Jag går utan svårigheter □
Jag kan gå men med viss svårighet □
Jag är sängliggande □

**Hygien**
Jag behöver ingen hjälp med min dagliga hygien, mat eller påklädning □
Jag har vissa problem att tvätta eller klä mig själv □
Jag kan inte tvätta eller klä mig själv □
Huvudsakliga aktiviteter (t ex arbete, studier, hushållsarbete, familje- och fritidsaktiviteter)

Jag klara av mina huvudsakliga aktiviteter □
Jag har vissa problem med all klara av mina huvudsakliga aktiviteter □
Jag klara inte av mina huvudsakliga aktiviteter □

Smärtor/besvär

Jag har verkan smärta eller besvär □
Jag har måttliga smärtor eller besvär □
Jag har svåra smärtor eller besvär □

Oro/nedstämdhet

Jag är inte orolig eller nedstämd □
Jag är orolig eller nedstämd i viss utsträckning □
Jag är i högsta grad orolig eller nedstämd □

Till hjälp för att avgöra hur bra eller dåligt ett hälsotillstånd är, finns den termometer-liknande skalan till höger. På denna har Ditt bästa tänkbara hälsotillstånd markerats med 100 och Ditt särsta tänkbara hälsotillstånd med 0.

Vi vill att Du på denna skala markerar hur bra eller dåligt Ditt hälsotillstånd är, som Du bedömer det. Gör detta genom att dra en linje från nedanstående ruta till den punkt på skalan som markerar hur bra eller dåligt Ditt nuvarande hälsotillstånd är.