Thigh Pain After Cementless Total Hip Arthroplasty: Evaluation and Management

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Abstract

Data from short- and long-term follow-up studies indicate that thigh pain is a significant complication after apparently successful cementless total hip arthroplasty. In most cases, reported symptoms are mild to moderate, resolve spontaneously or do not progress, and require little or no therapeutic intervention. However, persistent thigh pain may be a source of dissatisfaction or may present as severe, disabling pain. Possible causes include bone-prosthesis micromotion, excessive stress transfer to the femur, periosteal irritation, or a mismatch in Young's modulus of elasticity that increases the structural rigidity of the prosthetic stem relative to the femur. Thorough diagnostic evaluation of thigh pain is essential to rule out prosthetic infection or loosening, stress fracture, or spinal pathology as the primary source. Treatment options in the aseptic, well-fixed femoral component include medical management, revision of the femoral component, or cortical strut grafting at the tip of the implant.

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Cementless total hip arthroplasty (THA) continues to gain popularity because of concerns about aseptic loosening of acetabular and femoral components used in early cemented THA techniques. However, unresolved thigh pain in apparently well-fixed femoral components after primary cementless THA is a clinical challenge. Despite stem design modifications and improved implantation techniques, the incidence of recalcitrant thigh pain with cementless designs ranges from 0.5% to 40%.[1-8] Most published series show that only a small percentage (<4%) of patients experience severe, disabling pain.[9] The incidence of thigh pain may increase or decrease depending on the duration of follow-up from the index procedure.[2-4,8,10] Understanding the potential etiologies, clinical presentation, and critical elements of the diagnostic evaluation are paramount for selecting the optimal treatment modality.

Etiology

The etiology of thigh pain is often multifactorial and can be categorized generally into factors related to micromotion at the bone-prosthesis interface, excessive stress transfer, prosthetic stem characteristics, host bone morphology, and endosteal/periosteal irritation. These factors probably are interrelated and may stimulate the final common pain mediators, the endosteum and periosteum.

Motion at the Bone-Prosthesis Interface

The goal of cementless techniques is biologic fixation, the process of bone and/or fibrous tissue growing into or onto the surface of the prosthetic femoral components. Immediate implant stability at the time of surgery is perhaps the single most important factor for achieving successful osseointegration with cementless prostheses.[11] When initial stability is not achieved at the bone-prosthesis interface, motion occurs, inhibiting bone ingrowth and/or stable fibrous fixation. Many authors have reported an increased correlation of thigh pain with radiographically unstable femoral components.[2,5,9,12] Whiteside[13] emphasized the importance of achieving a tight fit distally to prevent toggle of the stem within the medullary canal. In that study, 53% of patients with "loose" stem tips had thigh pain, compared with only 3% in those with a tight-fitting distal stem.

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In patients with radiographically stable implants, a potential source of thigh pain still may be micromotion of the tip of the stem.[14] The incidence of thigh pain in prostheses that are stable by fibrous fixation ranges from 28% to 34%, whereas prostheses of similar design that are stable with bony ingrowth have an incidence of approximately 8% to 10%.[11,15]

Excessive Stress Transfer

Excessive stress transfer from the stem to the host femur as a source of pain is based on the concept of a mismatch in stiffness or a relative difference in structural rigidity between the prosthesis and the surrounding host bone. Bending stiffness is the ability of a prosthesis to resist bending/deflection and is equal to the product of the material's modulus of elasticity and moment of inertia. The structural rigidity of a particular implant is determined by the choice of implant material (with its corresponding modulus of elasticity), stem geometry, and the stem diameter required for rigid fixation.

Stem Materials

The incidence of thigh pain among implants is influenced by the implant material, the rigidity of fixation to the femur, and the extent of porous coating. The materials most commonly used in manufacturing prosthetic stems are cobalt-chromium and titanium alloy (Ti-6Al-4V). For a given stem geometry and size, titanium implants have less structural rigidity because of a lower modulus of elasticity than do similarly designed and sized cobalt-chromium stems. Dujovne et al[16] compared two similarly designed stems for their respective axial, bending, and torsional stiffness characteristics: the cobalt-chromium AML (DePuy, Warsaw, IN) and the titanium alloy Harris-Galante Multilock (Zimmer, Warsaw, IN). The titanium stem was two to three times less stiff overall than the AML stem. Skinner and Curlin[17] described the "flexural rigidity" of components relative to bone. In their study of 101 hips (26 Harris-Galante Multilock, 49 AML, and 26 cobalt-chromium PCA ([porous-coated anatomic] Howmedica, Rutherford, NJ), there was a trend toward less thigh pain with more flexible stems. Namba et al[18] did a finite element analysis comparing femoral stresses (femur modulus = 12 GPa) imparted by implants with the elastic modulus of cobalt-chromium (220 GPa) or titanium (110 GPa). They reported a 30% increase in stress at the stem tip–anterior femoral cortical interface for cobalt-chromium compared with titanium. Burkart et al[10] reviewed 105 titanium Mallory-Head stems (Biomet, Warsaw, IN) and 110 cobalt-chromium PCA stems and found less thigh pain with the titanium stems (7% versus 13% at 1 year, 3% versus 23% at 2 years).

Stem Size

Prosthetic stems are manufactured in an array of diameters to accommodate the wide range of femoral canal sizes in patients undergoing THA. As implant size increases, implant stiffness or structural rigidity also increases unless one of the mechanical properties or design elements (eg, material composition, component geometry, slots, grooves, splines) is altered to offset the increase in size. Dujovne et al[16] compared the relative stiffness of 12-, 15-, and 18-mm stems of Harris-Galante Multilock and AML stems to cadaveric femurs. The 12-mm stems of both implants were less stiff than the cadaveric femurs in the isthmic region. The 15-mm AML stem was stiffer than the cadaveric femurs, whereas the 15-mm Harris-Galante Multilock stem was less stiff. The 18-mm AML stem was markedly stiffer than the bone. Vresilovic et al[19] reported that thigh pain was significantly ($P = 0.014$) influenced by prosthetic size in their series of 297 hips (271 patients) with a 12% incidence (36 hips) of symptoms at 1 year. The general trend indicated increasing incidence of thigh pain as femoral implant size increased.

Stem Design

The goal of stem design is to achieve rigid, durable, osseointegrated fixation without creating excessive stress shielding or extreme rigidity (stiffness) that might result in thigh pain. Manufacturers have modified their implants in an attempt to decrease structural rigidity. Strategies include the placement of a coronal slot in the distal aspect of the stem or a longitudinal groove to decrease the amount of material and thus decrease rigidity. Table 1 summarizes the relationship between design, porous coating, and incidence of thigh pain.

Extent of Porous Coating

Factors relevant to achieving an optimal porous surface include particle size in the coating, interconnectivity, and interconnection pore size.[20] More extensively coated implants may improve the likelihood of achieving solid fixation and may decrease the incidence of thigh pain secondary to a loose stem. However, the extent of porous coating does appear to influence the amount of proximal stress shielding, or resorptive remodeling, that occurs over time. Moderate to severe stress shielding seen with extensively coated prostheses may be associated with larger, stiffer stems, yet stress shielding also is a sign of a well-fixed component.[11] Proximal resorptive remodeling is uncommon with proximally coated implants,[6,29] although Martell et al[30] reported proximal cortical resorption (64% [77/121]) with the Harris-Galante femoral implant (noncircumferential porous proxi-

Table 1
Relationship of Porous Coating and Stem Design With Thigh Pain

Study	Coating	Design	Number of Hips	Follow-up (yr)	Thigh Pain	Comments
Bourne et al[2]	Proximal	Cylindrical, cobalt-chromium	101	5	27%	Loose beads on radiographs strongly correlated with incidence
Callaghan et al[3]	Proximal	Cylindrical, cobalt-chromium	50	2	18% at 1 yr, 16% at 2 yr	—
Campbell et al[28]	Proximal	Cylindrical, cobalt-chromium	148	2	22%	—
Kim and Kim[25]	Proximal	Cylindrical, cobalt-chromium	116	6.75	25%	Undersized/loose stems had highest incidence of pain
Moskal et al[26]	Proximal	Cylindrical, cobalt-chromium	134	3	5%	Incidence 9% at 1 yr, 6% at 2 yr, 5% at 3 yr
Whiteside[13]	Proximal	Cylindrical, cobalt-chromium	105	1	21%	Pain in 20/38 with loose and 2/67 with tight distal fit
Cameron[20]	Proximal	Modular, titanium	91	3.5	8%	2/5 solid stems, 2/43 coronal slotted stems with pain
Morrey[21]	Proximal	Short tapered, titanium	20	≥1	0%	—
Menon and McCreath[22]	Proximal	Tapered, titanium	68	5.5	40.4%	High rate of early loosening and subsidence
Burkart et al[10]	Midcoat	Tapered, titanium	105	2	3%	—
McLaughlin and Lee[23]	Midcoat	Tapered, titanium	98	10.2	2%	Average age at index procedure, 37 yr
Engh et al[11]	Extensive	Cylindrical, cobalt-chromium	307*	2	14%	11% (good preop bone quality), 26% (poor preop bone quality)
Engh and Massin[15]	Extensive	Cylindrical, cobalt-chromium	204*	5	7.8% in those with bony ingrowth and 34.3% in those with fibrous ingrowth	—
Engh et al[9]	Extensive	Cylindrical, cobalt-chromium	174*	11	8%	—
McAuley et al[27]	Extensive	Cylindrical, cobalt-chromium	381	9	12%	2.9% incidence of activity-disabling pain
Petrou et al[24]	—†	Tapered, titanium	51	4	1.9%	Isolated case resolved at 2 yr postop

* Same group of patients followed at intervals.
† Coating not specified.

mal pads). The extent of porous coating does appear to influence the amount of proximal stress shielding. Thus, there is a trade-off between the length of the coating, the occurrence of thigh pain, and the amount of stress shielding.

Host Bone Morphology

The relationship of the preoperative condition of the femoral host bone to postoperative clinical thigh pain has been addressed in several studies. Engh et al[11] reported on 243 patients with good preoperative radiographic bone quality who had an 11% incidence of postoperative thigh pain. Sixty-four patients with poor bone quality preoperatively experienced a much higher incidence (26%) of pain. Likewise, Moreland and Bernstein[31] noted a

markedly higher incidence of thigh pain in patients with preoperative radiographic osteopenia or femoral bone stock deficiency. Relative osteopenia may be consistent with bone with less mechanical stiffness. Therefore, the placement of a very stiff stem into the bone creates an abrupt transition zone between the end of the rigid stem-bone construct and the weak distal bone. In contrast, no positive correlation between thigh pain and type of femur was found by Bourne et al[2] and Burkart et al,[10] who classified femurs using Dorr's morphology[32] (A, funnel-shaped; B, intermediate to A and C; C, cylindrical or "stovepipe").

Basic studies of femoral bone mechanical properties (ie, Young's modulus of bone elasticity = 12 GPa) compared with the material qualities of contemporary implants (Ti-6Al-4V = 117 GPa, cobalt-chromium = 210 GPa) suggest differences in stiffness may contribute to thigh pain.[16,21,23,24] No conclusive evidence clearly proves or disproves the association of pain with radiographically identifiable physiologic changes in the femur (stress-shielding/resorptive remodeling and stem tip cortical hypertrophy).[3,10,18,33]

Endosteal/Periosteal Irritation

Bjurholm et al[34] demonstrated the presence of the neuropeptides substance P and calcitonin gene-related peptide in bone and surrounding soft tissues. These chemical mediators are associated with primary sensory neurons integral to nociceptive response. Periosteal irritation or hypertension may cause thigh pain in cementless THA.[35] Although it is not clear which etiologic theory or combination of factors generates thigh pain, the result usually is irritation of the femur and surrounding periosteum at the prosthetic stem tip. While proof of the periosteum as the pain modulator is lacking, clinical reports of treatment of thigh pain with cortical strut grafting may be successful in part by the denervation of the periosteum during the exposure and graft placement.[33,35]

Evaluation

Enigmatic thigh pain in cementless THA is a diagnosis of exclusion after elimination of other sources of postoperative pain, including those that are extra-articular and unrelated to the prosthetic reconstruction. A thorough history and physical examination should include investigation of both direct and indirect etiologies of the pain source (Table 2). The patient typically presents with a dull aching pain in the anterolateral thigh, with no history of systemic illness or recent trauma. Often the patient can localize the discomfort to a discrete area on the femur that correlates with the location of the prosthetic stem tip. This is in contradistinction to bursal pain, which tends to be more proximal at the level of the vastus tubercle and greater trochanter. Pain on initiation of activity that resolves with continued activity should raise suspicion of a loose prosthesis. Persistent pain that is not relieved with rest and continues through the night suggests infection and should be thoroughly evaluated, including determination of the Westergren erythrocyte sedimentation rate and C-reactive protein level. The temporal relationship of thigh pain to the index procedure can vary; some authors[2,28] have

Table 2
Differential Diagnosis for Sources of Hip and Thigh Pain

	Sources	
Location	Direct	Indirect
Groin	Acetabular loosening Infection Insufficiency fracture Pelvic fracture Iliopsoas tenosynovitis Wear debris synovitis	—
Anterior and medial thigh	Iliopectineal bursitis Adductor/quadriceps muscle strain	Pelvis inflammatory disease Retroperitoneal disease Upper lumbar radiculopathy Nephrolithiasis
Lateral hip and thigh	Femoral loosening Trochanteric bursitis Fascia lata syndrome Abductor muscle strain Enigmatic thigh pain Fracture/stress fracture Infection	Meralgia paresthetica
Posterior hip and thigh	Piriformis syndrome Sacroiliac joint disease	Radiculopathy L5 (lateral) S1 (medial) Spondylosis Spondylolisthesis Spinal stenosis

noted an increase in pain over time, whereas others have reported a decreased incidence of symptoms.[3,26] The severity of symptoms also varies; some patients report mild discomfort and others, symptoms (limp, ambulation tolerance, use of ambulatory assistive devices) severe enough to adversely affect clinical outcome.[27] Published series on patients with thigh pain collectively report a relatively small percentage (<4%) of patients with severe, disabling thigh pain who require treatment.[9]

The physical examination should include a thorough neurologic assessment of the lower extremities (eg, testing muscles manually, sensation, deep tendon reflexes) to rule out spinal pathology as the source of thigh pain. Both passive and active ranges of motion should be evaluated to assess implant stability. Palpation of the hip and thigh can isolate the location of the pain. Often, the patient will have a discrete tender area on the anterolateral thigh that corresponds roughly to the region of the tip of the implant.

Radiographic evaluation should begin with plain radiographs of the pelvis, hip, and femur to assess component position, bone-prosthesis interface, interval changes from previous radiographs, and signs of fracture. Engh et al[9,12] have established criteria for determining the type and extent of fixation of fully porous-coated femoral components. They categorized fixation into osseointegration, stable fibrous ingrowth, and unstable fixation. Radiographic signs of osseointegration include the absence of reactive lines around the porous portion of the stem and the presence of "spot welds" of trabecular bone from the host to the prosthesis. Calcar atrophy also indicates osseointegration in the diaphysis, with subsequent proximal stress shielding. Radiographic features of stable fibrous ingrowth include no progressive migration and the presence of parallel lines up to 1 mm wide along the stem with no local cortical hypertrophy. An unstable prosthesis is indicated by progressive implant migration >2 mm. Engh et al[12] also reported on a scoring system to assess component fixation and stability applicable to both proximally and fully porous-coated implants. The scoring system evaluates the appearance of the bone-prosthesis interface, reactive lines and radiolucencies around the component, pedestal development, calcar response, component migration, and particle shedding. This system is more reliable than intraoperative testing for implant stability, and high scores correlate with durable implant stability. Conversely, Callaghan et al[3] found no correlation of thigh pain or femoral stem fit with similar radiographic criteria in 50 PCA stems followed for a 2-year period.

Radionuclide imaging also has been used to evaluate cementless implants after THA. Herzwurm et al[6] reported the results of radionuclide bone scans on 57 hips (49 patients) followed for a 2.5-year period; 35 had cementless femoral implants and 22, cemented. There was a statistically significant higher uptake of marker at both the 1-year ($P = 0.0006$) and 2.5-year ($P = 0.00005$) follow-ups in the cementless compared with the cemented implants. There was a positive correlation between uptake and the development of cortical hypertrophy in the cementless stems; however, there was no statistical correlation between thigh pain and enhanced bone scan. Oswald et al[36] reported similar findings of persistent increased uptake on bone scans at 2 years with cementless implants, which did not positively correlate with thigh pain. The increased marker uptake and subsequent hypertrophy may indicate physiologic remodeling in response to stress.

Treatment

With clinical, radiographic, and laboratory confirmation that the THA is well fixed, stable, aseptic, and without an extra-articular source of thigh pain, initial treatment should consist of nonsurgical measures focused on symptomatic relief (Fig. 1). Nonsteroidal anti-inflammatory medications and activity modification, including the use of ambulatory assistive devices to limit weight bearing on the involved extremity, should be used judiciously. Water aerobic activity may help rehabilitate the muscles while limiting the weight on the symptomatic extremity. A thigh corset or Sarmiento sleeve for the thigh may be useful during stressful activity. Nonsurgical measures should be continued for 1 to 2 years after the index procedure, allowing for physiologic remodeling of the femur to the new stresses generated by the prosthetic reconstruction.

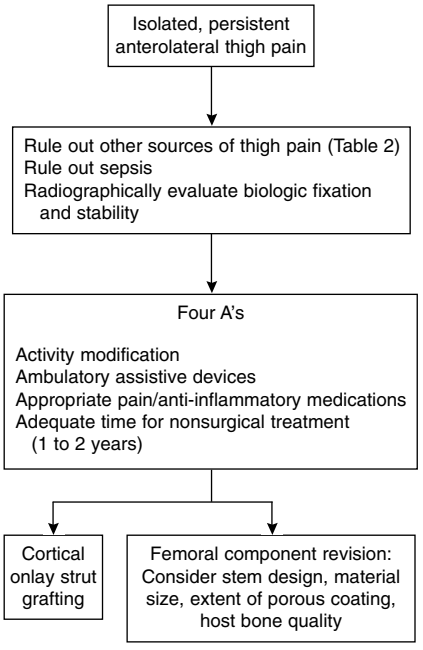

Figure 1 Treatment of enigmatic thigh pain.

Persistent, debilitating thigh pain may warrant surgical intervention, such as cortical augmentation of the femur at the level of the prosthetic stem tip or revision of the femoral component. Cortical onlay strut allografting of the femur involves a lateral subperiosteal exposure of the femur at the level of the stem tip, with subsequent placement of a well-sculpted diaphyseal strut spanning the stem tip by 7 to 8 cm both proximally and distally. The internal surface of the allograft strut should be contoured to provide excellent contact with the corresponding convexity of the lateral femur. The allograft strut should be rigidly cerclaged to the native femur with wires or cables. Cancellous autograft or allograft bone should be applied to the crevices between the strut and host femur (Fig. 2). Postoperatively, patients should bear weight to tolerance with ambulatory aids for 6 weeks, with rapid advancement to full weight bearing thereafter. Most patients treated with allograft struts applied to the femur for recalcitrant thigh pain have shown good to excellent results in several small series.[33,35] The theoretical rationale for this technique involves the increased structural rigidity of the femur after application and subsequent incorporation of the allograft. The increased rigidity of the augmented host femur may decrease the mismatch in structural rigidity between femoral component and bone, which has been hypothesized to cause the pain.[16,23,24] Pain relief also may be explained in part by the denervation of the periosteum during exposure and graft placement.

Revision THA should be done only when nonsurgical management fails and the patient continues to experience severe, disabling pain. Several issues must be taken into account: the surgical approach to implant removal and the component selection for the revision implant. Consideration should be given to implant design, size, material composition, method of fixation, and augmentation of the reconstruction with allograft struts. The goal of revision surgery is to achieve rigid, durable, pain-free fixation of the femoral component in the face of potential bone stock compromise from component removal or associated osteolysis. The outcomes of revision THA in managing recalcitrant enigmatic thigh pain have not been well documented.

Moreland and Bernstein[31] reviewed 174 hips revised with cementless porous-coated cobalt-chromium stems (AML and Solution; DePuy). The prerevision diagnosis did not specify the failure mode responsible for the revision arthroplasty. The overall incidence of thigh pain at an average 5-year follow-up was 36% (62/174); severe symptoms were reported in 8% (14/171). Stable fibrous and unstable patterns were more likely to be associated with thigh pain than were bone-ingrowth patterns. Patients with stable osseointegration with moderate to severe preoperative osteoporosis were more likely to have thigh pain than were patients with minimal preoperative osteoporosis.

Paprosky et al[37] reviewed 170 patients who underwent revision with the AML or Solution stem and were followed for a minimum of 10 years. The revisions were done after patients experienced septic or aseptic loosening, periprosthetic fracture, or femoral malpositioning. The incidence of thigh pain was 31%. Twenty-two percent of patients had minimal symptoms, whereas 9% experienced significant thigh pain that limited activity or required medication. All patients with radiographically unstable stems (4%) reported thigh pain. The authors did not find a specific correlation between stem size and thigh pain. Both studies[31,37] showed a link between thigh pain and use of cementless porous-coated cobalt-chromium stem designs.

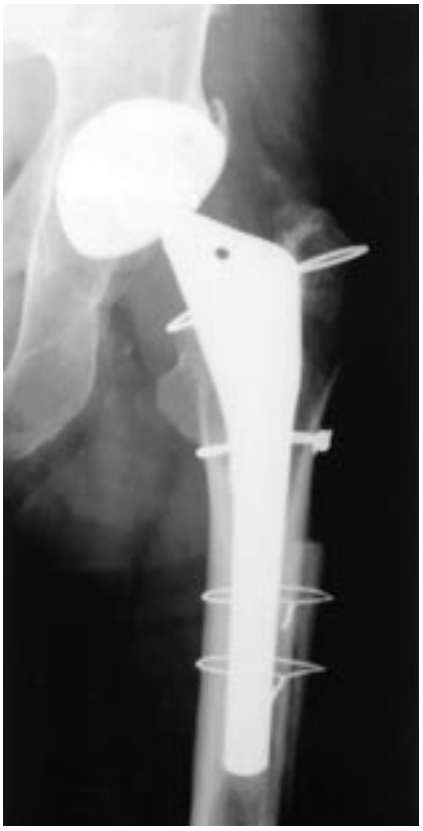

Figure 2 A 66-year-old man had debilitating thigh pain for 1 year after cementless THA. Because the stem appeared to be radiographically stable, grafting was done without exposure of the hip joint. Thigh pain resolved completely by 6 weeks postoperatively. This anteroposterior radiograph 6 months after cortical strut grafting shows progressive graft incorporation.

Cameron[20] reported on 91 complex hip revision cases using the S-ROM proximally porous-coated modular femoral stem (DePuy) followed for 2 to 6 years and found no patients with end-of-stem thigh pain. Chandler et al[38] followed 48 patients (52 hips) revised with the S-ROM stem and reported thigh pain in 25% (13/52) at 1 year and 9.6% (5/52) at 2 years. Marked thigh pain was noted in 4% (2/52). Both patients had stems with diameters >17 mm.

Summary

Persistent thigh pain after successfully osseointegrated cementless THA remains a clinical challenge in a small percentage of patients. A thorough investigation to rule out loosening, infection, or extra-articular sources of pain should be done before undertaking definitive treatment. Initial treatment should be nonsurgical, such as judicious use of oral nonsteroidal anti-inflammatory drugs and activity modification. If symptoms do not resolve 1 to 2 years after THA and activity remains severely limited because of thigh pain, surgery should be considered. Cortical onlay strut grafting of the femur at the prosthetic stem tip can be effective for refractory thigh pain. Pain relief may be secondary to increased bending stiffness of the host bone, periosteal denervation, or both of these factors. Cortical strut grafting avoids the need for removal of a well-fixed femoral implant and the associated morbidities. If revision of the femoral component is chosen for definitive treatment, consideration should be given to the implant material, geometry, mode of fixation, and expected longevity to minimize the risk of persistent thigh pain after revision.

Recommendations for future investigation include the evaluation of recent implant modifications (eg, slots, grooves, splines) and their effect on decreasing enigmatic thigh pain. Additionally, continued research is needed in the development and use of composite stems designed to match closely the modulus of elasticity of bone and theoretically decrease the incidence of enigmatic thigh pain. Furthermore, a critical clinical evaluation of the surgical outcomes of strut grafting versus femoral component revision is needed to determine the most efficacious method of treatment for enigmatic thigh pain.

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