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Total THA in Adult Osteonecrosis Related to Sickle Cell Disease

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Abstract Most previous studies of THA in sickle cell disease report high risks of medical and orthopaedic complications, including infections and a higher incidence of failure than observed after THA for osteonecrosis related to other conditions. Based on our experience (1245 orthopaedic procedures during the last 25 years), we questioned these conclusions and retrospectively reviewed 312 arthroplasties performed in 244 patients with sickle cell disease. The mean age of the 126 women and 118 men at the time of surgery was 32 years. The minimum followup was 5 years (mean, 13 years; range, 5–25 years). We revised 10 hips (3%) for infection at a mean 11 years (range, 7–15 years) after the primary procedure and revised 21 cups (8%) and 17 stems (5%) for aseptic loosening at a mean of 14 years. We observed medical complications after 85 operations (27%) and orthopaedic complications in 42 cases (13%). Although THA carries a high risk of complication in patients with sickle cell disease, the benefits for the patient are substantial, and the risk of revision for loosening or infection appeared less than described in previous literature.
Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.
Each author certifies that his or her institution either has waived or does not require approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.
The corresponding author confirms four authors were required to design the study and all authors participated in a material way in at least three elements of the study and report.

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Introduction

Sickle cell disease is an autosomal-recessive disorder that produces hemolytic anemia related to abnormal hemoglobin and erythrocytes. Those who are homozygous for the sickle cell gene (hemoglobin SS) have a high risk of bone osteonecrosis resulting from microvascular occlusion in relation to the disturbance in the erythrocyte architecture, the polymerization of hemoglobin S (in a deoxygenated state) producing cells that are crescent- or sickle-shaped with decreased deformability; the decreased deformability results in greater risk for clotting in small vessels. The incidence of osteonecrosis is also high in patients with hemoglobin SC (compound heterozygotes for HbS- and HbC-producing alleles: SC) and in the various types of sickle-beta-thalassemia (SThal) population.

For young patients who have avascular necrosis related to sickle cell disease (SCD), the hip is one of the most limiting factors in their life in terms of pain, level of activity, and function [19, 23, 24]. These young patients tend to be highly motivated and often are willing to accept the risk of implant failure in exchange for relief of pain and independence the operation may provide at what many patients consider the most crucial time in their personal and professional lives. The treatment of these young patients is particularly important not only for socioeconomic and humanitarian reasons, but also because of their life expectancy. The treatment of even the most severe forms

of this disease have substantially improved in recent years with advances in hematologic, visceral, and infectious disease management [42, 43]. With pharmacologic treatments including analgesia, oxygen therapy, hydration, and hydroxyuera [6, 40], the lifespan of the patient with SCD can be extended into the 60 s [38].

In previous reports [1, 4, 7, 14, 16, 34] of THA the overall failure rate ranged from 31% to 63% even with average followups of less than 5 years (Table 1). For example, Hanker and Amstutz [16] reviewed eight arthroplasties of the hip and showed in a survivorship analysis that a failure rate of 50% could be expected at 5.4 years. Acurio and Friedman [1] reported 14 of 25 hip arthroplasties that were revised by 7.5 years after surgery, and nine others were radiographically or symptomatically loose. Their complication rate was 49%, and the infection rate was 20%. Moran et al. [34] found a 38% failure rate in 13 primary hip arthroplasties as a result of aseptic loosening and infection, with a 43% failure rate in revision arthroplasties. The benefit of THA for patients with sickle cell disease has therefore been controversial, and many surgeons remain reluctant to perform THA even in late stages of hip osteonecrosis. Many believe the high rates of failure would inevitably result in little or no improvement of pain and function and result in the need for technically demanding revision operations while the patient is still young.

However, most of these series were reported 15 or more years ago and many of these early studies had limitations such as small numbers of patients, short duration of followup, and the use of various designs of implants. As a result, it is difficult to draw definite conclusions for these young patients with SCD. Since 1980, we have performed 1245 orthopaedic procedures in patients with SCD. Based on the limited data available in the literature and our personal experience, we questioned these results and presumed the outcomes would be better when these patients had surgery performed by a highly experienced team in SCD with multidisciplinary management.

We asked whether THA provided substantial long-term pain relief and improved function in this population. We also asked other questions: What was the influence of transfusion and anticoagulation on the prevention of medical complications (bleeding, alloimmunization, acute chest syndrome, and venous thrombosis)? What was the efficiency of antibiotics on the prophylaxis of infection? Was the rate of implant failure as high as reported in the literature with an experienced team?

Materials and Methods

We retrospectively reviewed 244 consecutive patients (312 THAs) with SCD who underwent surgery from 1980 to 2000. All the patients had osteonecrosis as an adult (average age, 32 years; range, 18–51 years), and all hips were Stage IV or more according to the Steinberg classification [41]. One hundred forty-five of the 244 patients were homozygous for the sickle cell gene (hemoglobin SS), 87 had hemoglobin S/hemoglobin C, and 12 had hemoglobin S associated with beta-thalassemia. There were 126 female patients and 118 male patients; 34 patients had staged bilateral arthroplasty. The minimum followup (up to the time of death, revision of one component, or the latest clinical evaluation) was 5 years (mean, 13 years; range, 5–25 years). No patient was lost to followup.

The medical status and attempts to prevent complications were monitored by a medical team experienced in the preoperative management of 1245 patients with SCD undergoing orthopaedic procedures as well as in the management of other surgical procedures and complications in 2300 patients with SCD. All patients had a preoperative evaluation, including hematologic consultation. Given the frequency of antigen mismatch between mostly white donors and recipients of African descent, and in an attempt to prevent alloimmunization, we have used blood products phenotypically typed for ABO, Rhesus (Cc, D, Ee), and Kell for 15 years. All patients had antibody screening before surgery. The donor registry for the entire country was used as a resource when necessary. Red blood cell exchange to decrease the hemoglobin S level to less than 30% was performed preoperatively in only 25 patients with

Table 1. Rates and causes for revision in the literature

Study	Study period	Number of cases	Followup (years)	Infection rate	Aseptic loosening		Revision rate
					Acetabulum	Femur	
Acurio and Friedman [1]	1970–1986	20 PTHA 15 PHA	8.6	20% (7/35)	46% (16/35)		40% (14/35)
Bishop et al. [4]	1974–1984	13 PTHA	7.5	23% (3/13)	8% (1/13)	None	31% (4/13)
Hanker and Amstutz [16]	1971–1984	8 PTHA	6.5	25% (2/8)	25% (2/8)		63% (5/8)
Moran et al. [34]	1973–1988	13 PTHA 7 RTHA	5	10% (2/20)	25% (5/20)	5% (1/20)	40% (8/20)
Present study	1980–2000	312 PTHA	13	3% (10/312)	8% (25/312)	8% (24/312)	13.5% (42/312)

PTHA = primary total hip arthroplasty; PHA = primary hemiarthroplasty; RTHA = revised total hip arthroplasty.

a history of severe acute chest syndrome [46], a previous cerebrovascular episode, or severe anemia with hemoglobin less than 5 g/dL. Acute chest syndrome is characterized by a combination of respiratory symptoms, pain in the thorax or abdomen, fever, an abnormal chest examination, and eventual development of an infiltrate on chest radiograph. This syndrome is often recurrent and affects 20% of those with SCD. Although there is great variability in outcome, acute mortality rate is as high as 5%. Furthermore, acute chest syndrome is a major risk factor for chronic lung disease. The etiology of this syndrome is a complex interplay of venous pulmonary embolism and/or fat embolism, infection, and in situ microvascular plugging by sickled red cells. Consequently, many [45] advocate exchange transfusion before surgery for patients with acute chest syndrome, and our experience with postoperative acute chest syndrome supports this recommendation. For the other patients, acute simple transfusions were performed during and after surgery to maintain a level of hemoglobin between 8 g/dL and 10 g/dL. Patients had surgery only when white blood cell count, erythrocyte sedimentation rate, and C-reactive protein values were within normal limits (according to the disease).

We took the following steps to prevent infection before, during, and after surgery. All patients with gallstones had their gallbladder removed before hip surgery because gallbladder infection is a major source of secondary bone infection. Antibiotics (first- and second-generation cephalosporins, 2.5 g per day) were administrated during surgery and for 3 days after. All the patients had their implants fixed with cement containing antibiotics (Palacos Genta; Heraeus Medical Gmbh, Hanau, Germany). Owing to the reported high frequency of osteomyelitis in SCD [8], we collected intraoperative aspirates, smears, and excised specimens before antibiotic administration and cultured for growth of aerobic and anaerobic bacilli. Histologic sections were examined for evidence of bacterial infection.

Surgery was performed by the senior orthopaedic surgeon (PH) with a posterolateral approach and general anesthesia with meticulous control of oxygenation and hydration. Patients received the same implants used for osteonecrosis related to other causes or for osteoarthritis. The prostheses were manufactured by Ceraver (Ceraver Osteal, Roissy, France). The stem was made of anodized titanium alloy (TiAl6V4) and was smooth and always cemented. The alumina head was 32 mm in diameter and anchored through a Morse taper. The acetabular component was a polyethylene cup and was always cemented. Both components were fixed with cement (Palacos G; Heraeus Medical Gmbh) containing antibiotics (gentamycin). The most common complication observed during surgery in these patients was femoral perforation in relation to areas of dense bony sclerosis with complete obliteration of the medullary canal and with abnormalities in the femoral version. To avoid the risk of perforation, preparation of the femur was performed by introducing a guidewire in the medullary canal followed by enlargement of the canal using incrementally sized conical reamers. Technical difficulties on the acetabulum were related to bone that was usually soft with isolated areas of dense bone that could lead to eccentric reaming. When protrusio acetabuli was present, an acetabular ring with a cemented cup was used to improve the fixation of the prosthetic cup. All patients received postoperative thromboembolic prophylaxis for 30 days. Two different anticoagulation protocols were used in the study period. During the first period from 1980 to 1995, 136 patients (182 hips) received warfarin. During the second period from 1995 to 2000, 108 patients (130 hips) received low-molecular-weight heparin.

After the operation, antibiotics were continued for 3 days if intraoperative cultures were negative and for 1 month if the cultures or histologic examination were positive. All patients had oxygen saturation monitored during the first postoperative week and were treated with anticoagulants (Sintrom, Novartis Pharma SA, 92500 Rueuil-Malmaison, France; Lovenox, Sanofi Aventis, Paris, France) postoperatively for 1 month.

We evaluated patients annually with clinical and radiographic evaluations. We (PH, SZ, GM, AP) assessed preoperative and postoperative pain, function, and range of motion graded with the Merle d'Aubigné and Postel scale [32]. We defined medical complications in the postoperative period by blood loss, the number of units transfused, and any transfusion-related complications; the number of thrombotic complications and the complications related to thromboembolic prophylaxis as hematoma; the number of vasoocclusive crises; and the occurrence of acute chest syndrome. We defined orthopaedic complications as the number of abnormal events during surgery (prolonged surgical time resulting from technical difficulties on the acetabulum or femur, femoral perforation, fracture of the femur) and as the number of postoperative complications, including abnormal postoperative hemorrhage, wound hematoma undergoing evacuation, dislocation, and neurologic complications. We classified heterotopic ossification according to the Brooker et al. [5] system, but used no specific measures to prevent it. The frequency of preoperative infection in this population was evaluated according to the number of patients with a previous infection in the site of the prosthesis documented as previous osteomyelitis in the proximal part of the femur, as a positive culture observed on the excised specimens, or as evidence of infection on the histologic specimens. The ratio of postoperative infection was defined as the percentage of patients with early infection to the percentage of patients with late infection requiring revision arthroplasty.

We (PH, SZ, GM, AP) assessed the stability of the acetabular component according to the method of Hodgkinson et al. [26] and that of the femoral components with the methods of Gruen et al. [13], Loudon and Charnley [30], and Loudon and Older [31] Definite loosening was defined as subsidence of more than 5 mm or continuous demarcation around the stem. An acetabular cup was considered definitely loose if it had migrated more than 5 mm.

We used the Kaplan-Meier method to calculate the probability of retention of the original prosthesis from the time of the initial operation until one of the following points: revision for infection, revision of either component for aseptic loosening, and revision of the femoral stem or revision of the cup for aseptic loosening. Survivorship with no loosening was also described for the cup and the stem. The chi square test was used to analyze differences between groups of patients with the level of significance set at $p < 0.05$.

Results

Patients improved in terms of relief of pain, function, and range of motion. The average score for pain was 2.5 points (range, 1–3 points) preoperatively and 5.8 points (range, 5–6 points) postoperatively. After the operation, 201 of the 312 hips (64%) were entirely free of pain and the remainder had only occasional discomfort. The score for function averaged 3 points (range, 1–4 170 points) preoperatively and 5.4 points (range, 4–6 points) postoperatively, because most of the patients were able to walk more than 1 km. The score for the cumulative range of motion of the hip averaged 3.1 points (range, 1–6 points) preoperatively and 5.2 points (range, 4–6 points) postoperatively.

We observed medical complications after 85 of the 312 operations (27%) (Table 2). The average blood loss was 950 mL (range, 310–3200 mL). The intraoperative blood loss resulted in intraoperative cell transfusion (average, 2 units; range, 1–4 units) and postoperative cell transfusion (average, 2 units; range, 2–6 units) in all but two patients. Twelve patients had painful postoperative sickling crises despite preoperative, intraoperative, and postoperative transfusions. The number of crises was similar in the 25 patients who had aggressive preoperative transfusion and the others. The blood loss was similar for the 21 patients who had hydroxyurea as medical treatment before surgery and the other patients without hydroxyurea as medical treatment. Blood loss and the number of units transfused were higher ($p = 0.003$) for the 25 patients who had aggressive preoperative transfusion before surgery and for the 71 patients who had preoperative alloantibodies. Minor complications from transfusions were observed in 62 cases and major complications in nine cases. Febrile, nonhemolytic reaction was a frequent complication of red blood cell transfusion after THA even with leukodepleted red blood cells. This was observed at a rate of 19% (62 cases) and was associated with symptoms such as fever and pain complicating subsequent postoperative management, increasing the number of days of hospitalization. Major transfusion reactions were encountered in nine cases (12%) despite the use of extended Ag-matched blood; nine cases of severe alloimmunization were observed after transfusion. These nine patients developed massive intravascular hemolysis

Table 2. Complications for the 312 total hip arthroplasties

Medical and surgical complications		Rate and number	Description of complication	Rate of each complication
Medical complications		28% (87/312)	Postoperative sickling crises	3.8% (2/312)
			Minor transfusion reactions	19.9% (62/312)
			Major transfusion reactions	2.9% (9/312)
			Acute chest syndrome	1.3% (4/312)
			Deep venous thrombosis	0.3% (1/312)
			Pulmonary embolism	0.3% (1/312)
Surgical complications	Intraoperative complications	13% (10/312)	Femoral perforation	1.9% (6/312)
			Repeat fixation of the cup	1.3% (4/312)
	Postoperative complications	7.7% (24/312)	Wound hematoma	1.3% (4/312)
			Peroneal nerve palsy	0.6% (2/312)
			Heterotopic ossification	3.8% (12/312)
			Dislocation	1.9% (6/312)
	Late complications	9.9% (31/312)	Infection	3% (10/312)
			Isolated acetabular wear	1% (3/312)
			Aseptic acetabular loosening	9% (28/312)
			Aseptic femoral loosening	8% (24/312)

7 days after transfusion. Four patients who had massive hemolysis, jaundice, and elevated liver enzymes needed hospitalization in the intensive care unit for 10 days. Acute chest syndrome was observed as a first specific occurrence in four patients who had no preoperative aggressive transfusion before surgery. The clinical scenario was characterized by a combination of respiratory symptoms, pain in the thorax or abdomen, fever, increased leukocyte count, and abnormal chest examination and an infiltrate on the chest radiograph; the patients were managed with red blood cell exchange, oxygen to maintain saturation above 97%, pain control, and intravenous hydration. One of the patients with acute chest syndrome required ventilatory support for 3 days. One patient had deep venous thrombosis, and one had a nonfatal pulmonary embolism despite thromboembolic prophylaxis with warfarin.

We observed orthopaedic complications (Table 2) in 42 of the 312 cases (13%). As a result of osteonecrosis in the metaphysis and in the diaphysis, areas of dense bone sclerosis and obliteration of the medullary canal were observed in 46 femurs. Reamers were used in this situation. However, perforation of the femur occurred in six patients during surgery and three patients had additional plates and screws (owing to the site of the perforation). The acetabular bone was usually soft as a result of marrow hyperplasia with bleeding from the cancellous bone. An acetabular ring was used in six cases. This bleeding was the cause of difficult fixation of the cement in four cases with the need for repeat fixation of the cup during the same procedure in these four cases. The excessive intraoperative blood loss contributed to an increased incidence of wound hematoma and prolonged drainage (more than 5 days) in four patients (among the 136 patients who received thromboembolic prophylaxis with warfarin). The number of hematomas was considerably lower in the 108 patients who received low-molecular-weight heparin, because none had hematoma. Two patients (0.6%) had postoperative transient peroneal nerve palsy (3 months) with foot drop in relation to hematoma. During the first 3 postoperative weeks, six patients had early dislocations. No late dislocations occurred. Twelve of the 312 hips (4%) had heterotopic ossification; six were rated Class 1, four were rated Class 2, and two were rated Class 3 according to Brooker et al. [5] No hip had complete ankylosis (a Class 4 rating), and only two (those that had a Class 3 rating) had ossification that was considered clinically important.

A previous preoperative infection had occurred in 21 of 312 hips (7%). This previous infection was documented by patient histories or by the cultures obtained during surgery. Twelve patients had positive cultures from intraoperative aspirates. All 12 were treated with antibiotics for 1 month and none had clinically evident infection either postoperatively or in followup. No immediate postoperative infection occurred in the other patients, but late infection occurred in 10 hips (3%) (Table 2); none of these patients had positive intraoperative cultures. The average time to revision for infection was 11 years (range, 7–15 years). Among the 21 patients who had hydroxyurea as medical treatment after surgery, three had infection (14%). The organisms cultured at the time of revision for infection were Staphylococcus aureus, Acinetobacter, Proteus, and Pseudomonas. With revision for septic loosening as an end point, the probability of survival without infection at 10 years and 15 years was 98% and 97%, respectively. Revision for infection was performed with the "two-stage technique" performed 45 days after removal of the primary arthroplasty. At the most recent followup, eight of these 10 hips were without infection, and two had recurrence of infection.

With revision for aseptic loosening as the end point, the probability of survival of both original components at 10 and 15 years was 91% (95% confidence interval, 88%–94%) and 86% (95% confidence interval, 82%–90%), respectively. Twenty-one acetabular components (7%) had been revised at an average time of 13 years (range, 6–8 years). Seventeen acetabular components (5%) had been revised because of aseptic loosening without excessive wear and three (1%) because of loosening associated with excessive wear (which had resulted in acetabular osteolysis); the remaining acetabular component had been removed at the time of revision of a loose femoral component because it had been in place for more than 10 years and had marked wear. Considering revision for aseptic loosening of the acetabular component, the probability of survival of the original cup at 10 and 15 years was 95% and 92%, respectively. Seventeen femoral components (5%) had been revised for aseptic loosening an average time of 15 years (range, 7–17 years), which corresponds to a probability of survival of the original femoral component of 98% at 10 years and 94% at 15 years. Seven femoral stems were definitely loose, although the patients remained asymptomatic, and eight cups (3%) had migrated and were definitely loose, although the patients remained asymptomatic. Survival free from loosening for both the cup and the stem at 10 and 15 years was 87% and 81%, respectively.

Discussion

Patients with osteonecrosis related to SCD can be severely disabled by the status of their hip. THA remains the only surgical option for some of these patients given the severe degenerative changes after collapse. However, because the results of early reports of THA (Table 1) were poor (high rates of medical and surgical complications up to 50%, infection rates approaching 20%, and loosening with

revision), the benefit of this operation in this population was not evident. We believed, however, these rather poor results did not reflect our experience and therefore reviewed our data to see whether THA provided substantial long-term pain relief and improved function in this population and whether the rates of medical complications, orthopaedic complications, infections, and implant failure were as high as those in the literature.

With our experienced SCD team and the multidisciplinary management of the patients undergoing THA, our rates of complications were lower than those observed in the literature. However, our data do not indicate complete safety of THA in this population. By comparing the outcomes of our patients with those of the literature, our results can help patients and physicians to better understand the relative risks and outcomes of this procedure in this population. Like with all studies in the literature, ours is retrospective. The analyses of medical and surgical complications were limited by the lack of clinical detail and by the fact that the operative techniques and implants were different.

With a minimum of 5 years and a mean of 13 years followup, our data suggest good functional results in the long term for THA in SCD. We found THA was associated with a general improvement in range of motion and function of the hip as well as relief of pain. Survival of both of the original components at 10 years was 89%. Our improvement in the results of THA in this population have been confirmed by other recent series [2, 25, 27] with shorter followup.

Medical complications related to patient hematologic status are frequent in all the series [10, 12, 15, 47]. Increased transfusion in SCD is related both to the increased intraoperative blood loss that occurs during surgery and to the thromboembolic prophylaxis after surgery (much more when thrombosis prevention was based on warfarin derivatives). Blood loss during surgery is in relation to chronic marrow hyperplasia as a consequence of anemia. This marrow hyperplasia is present particularly on the acetabular side. Blood loss during surgery is also related to the difficulties encountered with the femoral canal preparation. The average blood loss (both intraoperative and postoperative period) for our patients was 950 mL compared with an average of 1200 mL in the literature for THA in SCD [12, 39, 45, 47]. Intraoperative blood loss was not reduced by a previous treatment with hydroxyurea [6, 40], which increases the fetal hemoglobin concentration (resulting in improved red blood function and a lower incidence of sickle cell crises). Blood loss increased when patients had many preoperative transfusions, alloantibodies, or red blood cell exchange with aggressive transfusions before surgery. This is in agreement with other reports in the literature [45–47]. Two commonly used transfusion techniques exist in THA: simple transfusions to increase the hemoglobin level to 10 g/dL and aggressive transfusions to decrease the hemoglobin S level to less than 30%. From a theoretical point of view, preoperative transfusion results in better rheologic characteristics and enhanced oxygen-carrying capacity of the erythrocytes. This facilitates an increase in overall microvascular perfusion, which should be associated with a decrease in the risk of postoperative sickle cell crises. In our experience, by adopting simple transfusion therapy, the frequency of postoperative sickle cell crises was similar to that in the literature [15, 47]. We frequently observed minor complications such as febrile reaction after transfusion. These complications appear minor but should be recognized because patients with SCD and a history of febrile transfusion reactions should have leukocyte-reduced blood. This excessive intraoperative blood loss can contribute to a high incidence of hematoma and prolonged drainage and may be a cause of infection. We institute antibiotic prophylaxis (cephalosporins, 2.5 g per day) if patients have prolonged drainage or hematoma.

The principal risk in this series was late infection with Staphylococcus and Gram-negative organisms. We observed deep infection in 10 hips (3%). This is more than the usual rate of infection in THA, but it is in contrast to the higher rate of 6% to 20% that has been reported for hip arthroplasties in patients with SCD in previous series (Table 1), ranging from eight to 20 arthroplasties.

The infected bones of patients with SCD may contain patent organism. Lifeso [29] reported bacterial cultures were positive in a high number of bone cultures taken from the femoral head during THA. We identified 12 patients with positive cultures and treated them with a modified antibiotic regimen (adapted according to the bacterial infection); none developed clinically apparent infections. Patients with hematoma and abnormal prolonged surgical time remained under antibiotic prophylaxis for at least 10 days. Preoperative prophylaxis against salmonella has been recommended because of its frequency in SCD osteomyelitis [8]. A review of the reported organisms from all the series show salmonella has not been reported as a pathogen in infection of THA in patients with SCD. The frequency of infection with Staphylococcus observed in most series suggests the need for Staphylococcus postoperative prophylaxis also. However, Gram-negative organisms have also been reported in different series. This suggests organisms come from the gastrointestinal tract and indicates the need for Gram-negative preoperative antibiotic prophylaxis and the removal of the lithiasic gallbladder before surgery. However, it is doubtful postoperative prophylaxis is sufficient to prevent infection long term considering the recurrent episodes of sloughing of the intestinal mucosa resulting in enteric bacteremia. Another

cause of increased risk of late infection in patients may be immunoparesis related to medical treatment by hydroxyurea. Three patients in our series had infection and medical treatment by hydroxyurea. The lower rate of infection observed over the long term with our series may be explained by the fact that all the patients had systemic antibiotics and fixation of the implants with cement containing antibiotics. The antibiotic was gentamicin. One rationale for cemented fixation in SCD may be the prevention of infection with diffusion of antibiotics from the cement. It has been demonstrated in vitro and in vivo that the total time of delivery of antibiotics from cement is much longer than the period of effective concentrations in the wound discharge and drain. In one controlled study [9], the prophylactic effect lasted for a minimum of approximately 5 years and suggested the combination of local application of antibiotics from cement and systemic antibiotics was an association more efficient for prophylaxis than local antibiotics in bone cement alone or systemic administration of antimicrobial agents alone.

Little data exist about the risk of thromboembolic events [11, 12, 37, 47] in patients with SCD after THA and the best prophylaxis. Risk factors associated with vasoocclusion include activation of the clotting cascade that can facilitate thrombus formation and hyperviscosity as a complication of transfusion [45]. However, the frequency of deep vein thrombosis was not higher than for THA in other indications and using the same prophylaxis. One of our patients had documented deep venous thrombosis and one other a documented nonfatal pulmonary embolism. All the patients had a prophylactic anticoagulant for 1 month postoperatively without any routine screening procedure (such as Doppler). Thromboembolism did not appear a clinical problem in this population of patients. With warfarin, the frequency of hematoma was higher than with low-molecular-weight heparin (HBPM). The problem with HBPM is the risk of thrombopenia.

Although it occurs very rarely in adulthood, splenomegaly may be present and induce thrombopenic hypersplenism. After surgery, the high hematopoietic activity and the inflammatory response may induce noticeable thrombocytosis. We did not observe complications related to HPBM such as thrombopenia.

The principal medical complication after THA in SCD was not pulmonary embolism but acute chest syndrome. Pulmonary symptoms after THA should first be investigated as acute chest syndrome, which has been described [46] as responsible for a mortality rate averaging 2% after THA in patients with SCD. We had four cases of acute chest syndrome in the absence of preoperative aggressive transfusion. Treatment consisted of blood transfusions and hospitalization in the intensive care unit with oxygen saturation.

Aseptic loosening of the acetabular component occurred in 25 (8%) of the 312 hips in our study after an average followup of 13 years. Aseptic loosening of the femoral component was as common as that of the acetabular component. The incidence of aseptic loosening in the present study with patients who had SCD is also in contrast with the very high rate of loosening of 10% to 38% that has been reported in previous series with a very small number of patients and a short followup. In this series, we used cemented fixation both for the cup and the stem. Our revision rate was lower than the reported revision rate estimated between 30% and 50% within 5 years in other series (Table 1). The rationale for cemented fixation of the cup is that the necrotic bone has limited potential for bone ingrowth, and the fact that the soft areas of bone (resulting from bone marrow hyperplasia) are mixed with areas of dense bone leading often to eccentric reaming and difficult cementless fixation of the cup. The acetabular component was inserted by hand. The cup was inserted horizontally and then pushed medially first before being gradually angulated to the desired inclination of approximately 45°. Based on an elevated loosening rate with the use of cemented stems, some authors [17, 25] advocate the use of cementless stems in SCD. Our lower rate of loosening with cemented stems was probably in relation with the design of the stem and our technique of cementation particularly adapted for this disease. As a result of the disease, it is difficult to obtain a cementless fixation, but also a cement mantle of good quality by removing mechanically weak cancellous bone. We used the technique described as the "French paradox" technique [28] for the stem. We used a rectangular canal-filling stem with corners having a fillet radius of 5 mm after using the largest possible broach. On a technical level, we tried to fill the medullary femoral canal as much as possible with the largest possible stem without trying to obtain a continuous cement mantle. Because of the rectangular cross-section and a direct load transfer to bone by close cortical contact, the Ceraver Osteal stem had an intrinsic stability within the femur that may have protected the cement mechanically. The advantage of using a titanium alloy stem was also that the modulus elasticity of the stem is close to that of the bone.

THA in SCD involves a higher complication rate and incidence of failure with revision than arthroplasty in osteonecrosis related to other conditions [3, 33]. With one experienced surgical and medical team and multidisciplinary management of these patients [39] undergoing THA, our rates of complications were lower than those observed in the literature. However, our data do not indicate complete safety of THA in this population, but we believe the risk-to-benefit ratio reasonable. Even in late stages of osteonecrosis, this procedure is the most likely to provide substantial pain relief and improved function in

this population, which now has a life expectancy obviously greater than the prosthetic component survival. Other surgical options exist for early stages of this disease: core decompression and physical therapy [35, 36, 44], bone marrow transplant [20–22], and cementoplasty [18]. These treatments should be recommended at early stages of osteonecrosis to postpone the need for THA.

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