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Femoral Neck Fractures

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Abstract
Despite the tremendous advances in the science and practice of orthopaedic surgery, anesthesia, and perioperative care, repair of displaced fractures of the neck of the femur is still associated with complications in up to one third of patients. The risk of nonunion and osteonecrosis in particular is virtually the same today as in the 1930s. Recent data from well-designed outcome studies now indicate that the most predictable, durable, and cost-effective procedure for an active elderly patient with a displaced femoral neck fracture is total joint arthroplasty; however, not all patients are candidates for this procedure, and the potential complications of arthroplasty, including mortality, may be more difficult to manage and more severe than those associated with internal fixation. The laudable goal of obtaining fracture healing and maintenance of a viable femoral head can be successfully achieved in a number of patients.

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The femoral neck fracture is an increasingly common and still imperfectly treated injury that is associated with significant morbidity and mortality. The incidence of femoral neck fractures has reached epidemic proportions with profound implications for public health policy. In one recent article, the authors estimated that (assuming the age- and gender-specific incidence of fractures remains constant) the number of fractures in South Australia would increase by approximately 66% by the year 2021 and 190% by 2051.[1] In the United States, the average orthopaedist will treat an estimated 15 to 25 femoral neck fractures each year. It is possible that the health care costs associated with this injury alone will overwhelm the health care system.

In 1935, Speed[2] noted that the fixation of femoral neck fractures was associated with complications in up to 36% of patients. Recently published meta-analyses report that this complication rate is essentially unchanged today.[3] Two comparative studies published in 2002 came to opposite conclusions about the best treatment. In a randomized study of 455 patients, Parker and associates[4] concluded that hemiarthroplasty is preferable to internal fixation. In contrast, Partanen and associates[5] reported a matched-pairs analysis of 714 patients and recommended internal fixation. Thorough economic analyses of the cost of treatment of femoral neck fractures have clearly indicated that the cost of treatment is largely influenced by the cost of treating complications, which are not only expensive to treat but significantly impact patient function.[6] In general, arthroplasty for femoral neck fracture is associated with a dramatically lower complication rate than internal fixation, and the lower risk of revision after arthroplasty more than offsets the higher initial cost of this procedure.[7] Long-term outcome studies demonstrate that arthroplasty, especially total hip replacement, affords the best and most durable function.[7] Increasingly, surgeons are turning toward total hip arthroplasty as the best solution for the fit, active patient with a femoral neck fracture.

When treating a patient with a fracture of the femoral neck, the physician must consider patient age and expectations and choose the procedure that will provide an appropriate degree of function with minimal risk of complications. Most importantly, revisions must be prevented. For each age group, there are many unanswered questions and ongoing controversy about treatment. In the young to middle-aged patient with a femoral neck fracture, immediate anatomic reduction and internal fixation is warranted. Yet even among these healthy patients, approximately one third will experience nonunion or osteonecrosis, and a significant number will eventually require conversion to total joint arthroplasty.[8] The challenge in treating the young patient with a femoral neck fracture is to improve techniques of reduction and fixation to reduce these complication rates.

There is no real consensus regarding the treatment of active, elderly patients. Medicare data suggest that for persons older than 65 years, most patients with femoral neck fractures are treated with some form of prosthetic replacement. No one knows what the ideal proportion of patients receiving arthroplasty should be. Robinson and associates[9] demonstrated that the application of a standard decision-making algorithm based on a scoring system can significantly reduce the rate of complications after internal fixation in patients age 65 to 85 years. In the less active older patient, there is more general agreement that hemiarthroplasty is appropriate, but controversy exists regarding the use of unipolar versus bipolar femoral heads.

To practice true evidence-based medicine, one must turn to the literature for guidance. However, there is a dearth of high-level evidence available regarding femoral neck fractures. Although nearly 300,000 articles can be found in a Medline search for "femoral neck fracture," only a few dozen represent prospective randomized clinical trials. Most of these studies are comparisons of different variations of internal fixation or cover different aspects of the perioperative medical care of these patients; they are of limited value in deciding the best surgical approach for treatment of a fractured hip. Nevertheless, even for aspects of care with high-level evidence, such as the use of prophylactic anticoagulation, prophylactic antibiotics, and regional anesthesia, wide variations in care exist.[10]

Prevention is key in managing the impending epidemic of femoral neck fractures. Fall prevention, improved diagnosis of osteoporosis, and possibly the use of trochanteric pads may all contribute to a decrease in the incidence of femoral neck fractures.[11]

In this chapter, the basic evaluation, medical care, and rehabilitation of the patient with a femoral neck fracture, and treatment methods of internal fixation and arthroplasty will be reviewed. A review of the changing treatment of displaced femoral neck fractures in Europe adds a different perspective to the American experience.

Treatment Principles for Femoral Neck Fractures

General Principles

The primary goal of fracture treatment is to return the patient to the preinjury level of function. There is nearly universal agreement that this level of function can best be achieved with surgery.[12] Historically, nonsurgical treatment has resulted in excessive rates of medical morbidity and mortality, as well as malunion and nonunion. Nonsurgical treatment is appropriate only for selected nonambulators who experience minimal discomfort from their injury.[13,14] These patients should be rapidly mobilized to avoid the complications of prolonged recumbency—decubitus ulcers, atelectasis, urinary tract infection, and thrombophlebitis.

Clinical Evaluation

The clinical presentation of patients with a fracture of the femoral neck can vary widely depending on injury type, severity, and/or etiology. Displaced fractures are usually symptomatic; such patients cannot stand or ambulate. Patients who have a nondisplaced or impacted femoral neck fracture may be ambulatory and experience minimal pain.

It is important to determine the mechanism of injury. Most femoral neck fractures in the elderly are the result of a low-energy fall, whereas in young adults they are more often caused by high-energy trauma, such as from a motor vehicle accident. In high-energy trauma patients, associated head, neck, chest, and abdominal injuries should be assessed. Although patients with a femoral neck stress fracture usually deny specific trauma, they should be questioned about any recent changes in the type, duration, or frequency of physical activity. When trauma can reasonably be ruled out (such as in sedentary individuals with no history of injury), pathologic fracture must be considered.

The timing of the injury must be determined whenever possible. In elderly individuals who live alone, hospital presentation may be delayed hours or even days, by which time these patients are often dehydrated and confused; determining the exact day or time when the fracture occurred may be difficult. In addition, the potential for dehydration mandates evaluation of fluid and electrolyte status in these patients.

A careful, thorough medical history is important because of the impact of preexisting medical comorbidities on both treatment and prognosis. Cardiopulmonary disease (congestive heart failure, intermittent myocardial ischemia, or chronic obstructive pulmonary disease) is a common preexisting medical condition that impacts fracture management in the elderly, affecting the patient's ability to tolerate prolonged recumbency, undergo surgery, and participate in rehabilitation. Cardiopulmonary disease history is also a major determinant of the rating system used by the American Society of Anesthesiologists to assess surgical risk.[15] Injuries resulting from falls by these patients may cause further deterioration of already compromised cardiopulmonary function.

Neurologic conditions such as Parkinson's disease, Alzheimer's disease, and the residual effects of a previous cerebrovascular event must also be considered during treatment. Clinical manifestations in patients with Parkinson's disease range from mild tremors to complete incapacitation with severe contractures; well-controlled disease generally will not impact treatment decisions. Patients who have had a prior stroke are at increased risk for fracture secondary to residual balance and gait problems as well as osteopenia of the paretic limb.[16,17] Treatment of these patients may be complicated by the presence of osteopenia, spasticity, and/or contracture. The degree of involvement, as in Parkinson's disease, ranges from minimal to severe spasticity with contracture. For patients with Alzheimer's disease and severe cognitive dysfunction, a treatment plan requiring a high degree of patient cooperation would be inappropriate.

Radiographic Evaluation

The standard radiographic examination of the hip includes an AP view of the pelvis and an AP and cross-table lateral view of the involved proximal femur. The AP pelvic view allows comparison of the involved side with the contralateral side and can help to identify nondisplaced and impacted fractures. The lateral radiograph can help to assess posterior comminution of the femoral neck and proximal femur; a cross-table lateral view is preferred to a frog-lateral view because the latter requires abduction, flexion, and external rotation of the affected lower extremity and involves a risk of fracture displacement. An internal rotation view of the injured hip may be helpful to identify nondisplaced or impacted fractures. Internally rotating the involved femur 10° to 15° offsets the anteversion of the femoral neck and provides a true AP view of the proximal femur. A second AP view of the contralateral side can be used for preoperative planning. If a pathologic fracture is suspected on the basis of the patient's medical history or the appearance of the fracture, full-length AP and lateral radiographs of the entire femur should be obtained.

When a hip fracture is suspected but not apparent on standard radiographs, MRI scans should be obtained. MRI has been shown to be at least as accurate as bone scanning in identification of occult fractures of the hip and can be performed within 24 hours of injury.[18,19] MRI within 48 hours of fracture does not, however, appear to be useful for assessing femoral head viability/vascularity or predicting the development of osteonecrosis or healing complications.[20,21]

Laboratory Indices

Selective preoperative laboratory tests should be ordered for patients with confirmed fractures of the proximal hip. In the older patient, a complete blood cell count, electrolyte assessment with blood urea nitrogen and creatinine levels, electrocardiogram, and chest radiograph are probably sufficient. An arterial blood gas (as a baseline) is also probably warranted in older patients as well as in any patient with a history of a pulmonary disorder. Studies have demonstrated that the yield of nonselective laboratory testing to find clinically important abnormalities is low.[22] Additional laboratory studies should be ordered based on the medical history.

Initial Patient Management

All patients with a femoral neck fracture should be admitted to the hospital and maintained on bed rest. In the past, patients were routinely placed in 5 lb of Buck's skin traction to prevent further fracture displacement or additional soft-tissue injury that could compromise the vascular supply to the femoral head. Most authors currently advocate maintenance of the leg in a position of comfort—usually slight hip flexion and external rotation, supported by pillows under the knee. Several studies have shown that the extended position that results from Buck's traction increases intracapsular pressure, thereby diminishing femoral head blood flow.[23,24] Conversely, the position of external rotation and flexion allows for maximum capsular volume.

Surgical Timing

In general, hip fracture surgery should be performed as soon as possible after stabilization of all comorbid medical conditions; particular attention must be given to cardiopulmonary problems and fluid and electrolyte imbalances. In a series of 399 hip fracture patients, Kenzora and associates[25] reported that a surgical delay of less than 1 week to stabilize medical problems was not associated with increased mortality. Interestingly, they found that even healthy patients who underwent surgery within 24 hours of hospital admission had a 34% mortality rate at 1-year follow-up compared with a 5.8% mortality rate for those who underwent surgery between days 2 and 5. Conversely, Sexson and Lehner[26] found that relatively healthy hip fracture patients (with up to two comorbid conditions) who had surgery within 24 hours of admission had a higher survival rate than similar patients who had surgery after 24 hours. However, patients with three or more comorbid conditions had a poorer survival rate when undergoing surgery within 24 hours than those undergoing surgery after 24 hours. In a prospective series of 367 elderly patients with hip fracture, Zuckerman and associates[27] reported that a surgical delay of more than 2 calendar days from hospital admission roughly doubled the risk of the patient dying before the end of the first postoperative year.

Anesthetic Considerations

Although much has been written on the risks and benefits of the different anesthetic techniques, no significant difference in survival rates has been found in elderly patients with hip fracture who undergo surgery under regional versus general anesthesia.[28,29] Many anesthesiologists, internists, and surgeons believe that patients "look better" following regional anesthesia. However, studies have documented no difference in postoperative mental status in patients following regional or general anesthesia.[28,29] Studies have demonstrated the efficacy of regional anesthesia (spinal and epidural) in the prophylaxis of deep venous thrombosis (DVT) and pulmonary embolus.[30] Because pulmonary embolism is a significant cause of morbidity and mortality in this population, regional anesthesia may be preferable, especially if the patient is at increased risk for thromboembolic complications and there are other medical factors that compromise use of thromboprophylaxis.

Thromboprophylaxis

The rates of total and proximal DVT after hip fracture without prophylaxis, derived from prospective studies in which venography was performed, are approximately 50% and 27%, respectively.[31-44] Fatal pulmonary embolism has been reported in the range of 1.4% to 7.5% within the first 3 months after hip fracture.[45-47] In an autopsy study of 581 patients who died after hip fracture in a British hospital from 1953 to 1992, pulmonary embolism was the fourth most common cause of death, accounting for 14% of all deaths.[48] Factors that appear to further increase the risk of thromboembolism after hip fracture include increasing age, surgical delay, and the use of general (versus regional) anesthetic.[46,48-51]

Symptomatic thrombophlebitis and fatal pulmonary embolism can be prevented by use of thromboprophylaxis following hip fracture.[52] Thromboprophylaxis should be provided to all patients who sustain a fracture of the proximal femur. Two approaches might be considered to prevent fatal pulmonary embolism: (1) early detection of subclinical venous thrombosis by screening high-risk patients, and (2) primary prophylaxis using either drugs or physical methods that are effective for preventing DVT and pulmonary embolism. Several prophylactic measures have been recommended, including subcutaneous heparin, low-molecular-weight heparin, intravenous dextran, warfarin sodium, aspirin, intermittent pneumatic compression of the foot or leg, and various combined modalities.

Oral anticoagulant prophylaxis has been shown to be effective and safe in patients who sustain a fracture of the proximal femur. A randomized trial compared postoperative warfarin with aspirin or no prophylaxis.[41] The DVT rates in these three groups were 20%, 41%, and 46%, respectively ($P = 0.005$), whereas the proximal DVT rates were 9%, 11%, and 30%, respectively ($P = 0.001$). Rates of bleeding were similar across the three groups. Pooled results from three studies of adjusted-dose oral anticoagulant prophylaxis showed a reduction in relative risk of DVT of 61% (66% for proximal DVT) compared with no prophylaxis.[33,36,41] The reported bleeding rates for oral anticoagulant prophylaxis range from 0 to 47%,[33,36,41] with the most recent and largest trial finding no difference in bleeding compared to placebo.[41]

Low-molecular-weight heparin has been shown to lower the risk for DVT and proximal DVT after hip fracture.[32,34,37,39,41] Two studies found no significant difference in bleeding when low-molecular-weight heparin was compared with placebo[37] or with low-dose heparin,[39] although the sample sizes were small.

A recent review of prophylaxis methods after hip fracture included 31 trials and 2,958 patients.[53] Both unfractionated low-dose heparin and low-molecular-weight heparin were shown to protect against DVT (combined risk reduction was 40% compared with no prophylaxis) without increasing the risk for wound hematoma.

The synthetic pentasaccharide fondaparinux, a selective factor Xa inhibitor, has been investigated in patients after hip fracture.[34,54] Eriksson and associates[34] randomized 1,711 hip fracture patients to receive either subcutaneous enoxaparin (40 mg once daily started 12 to 24 hours postoperatively) or subcutaneous fondaparinux (2.5 mg started 4 to 8 hours after surgery). Preoperative initiation of enoxaparin or fondaparinux occurred in 26% and 11% of patients, respectively. The incidence of thromboembolism by postoperative day 11 was 19.1% (119 of 624 patients) in the enoxaparin group and 8.3% (52 of 626 patients) in the fondaparinux group ($P < 0.001$). Proximal DVT rates were also significantly reduced in the fondaparinux group (4.3% vs 0.9%; $P < 0.001$).

A meta-analysis has suggested that antiplatelet agents are effective in preventing postoperative thromboembolism after hip fracture.[55] None of the studies included in this meta-analysis, however, used routine contrast venography as an outcome measure. In the Pulmonary Embolism Prevention Trial, 13,356 hip fracture surgery patients in five countries were randomized to receive either prophylaxis with 160 mg of enteric-coated aspirin or placebo started before surgery (in 82%) and continued for 35 days.[56] Additional thromboembolic prophylaxis was allowed at the discretion of the attending physician and was done with graduated compression stockings, low-molecular-weight heparin, or low-dose heparin in 18%, 26%, and 30% of patients, respectively. Although the study's authors concluded that fatal pulmonary embolism and DVT were both significantly reduced by the addition of aspirin, the confounding and inconsistent use of other means of prophylaxis, as well as possible differences in anesthetic technique, make the conclusions of even this large trial open to criticism.

Elastic stockings are inexpensive, simple to use, and can be used in conjunction with other prophylactic measures. However, there is little evidence that graduated compression stockings provide any thromboprophylaxis when used alone. Intermittent pneumatic compression of the legs is an attractive form of prophylaxis that is effective in patients undergoing general surgery, neurosurgery, and prostatic surgery. Prophylaxis with intermittent pneumatic compression is virtually free of adverse effects and carries no risk of bleeding. External pneumatic compression overcomes venous stasis by intermittently squeezing the leg, and it also enhances fibrinolysis. Thus, intermittent compression has both a physical and a pharmacologic effect. At some institutions, an ultrasound of the venous system of both lower extremities is performed before placement of the external pneumatic compression devices to exclude the presence of preexisting thrombophlebitis. The role of intermittent pneumatic compression in patients undergoing hip surgery remains uncertain because of a lack of data concerning its effectiveness when used alone. One prospective, randomized study of 304 patients with hip and pelvic fractures compared pneumatic sequential compression devices to no specific prophylaxis.[57] As determined by follow-up venous Doppler duplex scans and ventilation perfusion scans, a statistically significant reduction in DVT and/or pulmonary embolism was found overall (11% in control patients and 4% in the experimental group; $P = 0.02$). When the results were stratified by fracture type (hip fracture compared with pelvic fracture), the sequential compression devices remained effective in the patients with hip fractures but were not effective in those with pelvic fractures.[57] Although the total DVT and pulmonary embolism rate may be lowered by mechanical compression devices, this study did not distinguish between proximal and distal DVT. A meta-analysis of total hip arthroplasty patients suggests that sequential compression devices may not be as effective in preventing proximal DVT compared with distal DVT.[58] This is a very real concern because even the combination of graduated compression stockings and subcutaneous low-molecular-weight heparin was found not to be effective in preventing proximal DVT in 644 patients with hip fractures.[59] The authors of this study recommend screening Doppler ultrasonography in all hip fracture patients to identify DVT.[59] Therefore, although these devices may contribute to a lower overall risk of thromboembolism, especially in patients in whom anticoagulation is contraindicated, the physician must still be vigilant for the development of thromboembolism despite the use of sequential compression devices.

Use of intermittent compression of the plantar venous plexus (foot pumps) for deep vein thromboprophylaxis has garnered recent interest. The pneumatic bladder of this device straps around the patient's foot in the region of the longitudinal arch. Although there are no data describing the efficacy of plantar compression in patients with hip fractures, Westrich and Sculco[60] performed a prospective, randomized study to assess the efficacy of foot pumps for prophylaxis against DVT after total knee arthroplasty. A group of 122 patients (164 knees) were randomized to receive thromboprophylaxis with either aspirin alone or foot pumps in conjunction with aspirin. The prevalence of DVT was significantly less in the foot pump group compared with patients managed with aspirin alone (27% versus 59%, $P < 0.001$). No proximal thrombi were noted in any patient who used the foot pump device, whereas the prevalence of proximal thrombosis in the popliteal or femoral veins was 14% in the group treated with aspirin alone ($P < 0.01$). No adverse effects were noted in any patient who used the foot pump device. The authors concluded that the use of foot pumps in conjunction with aspirin was a safe and effective method of thromboprophylaxis after total knee arthroplasty. However, the applicability of this method for hip fracture patients remains unknown.

Recently, the Seventh American College of Chest Physicians Conference on Antithrombotic and Thrombolytic Therapy was held.[61] Using evidence-based methodology, this group does not recommend the use of aspirin alone for thromboprophylaxis for any patient group. For patients undergoing surgery for repair of a hip fracture, the group recommends the routine use of either fondaparinux, low-molecular-weight heparin, warfarin (target International Normalized Ratio, 2.5; range 2.0 to 3.0), or low-dose unfractionated heparin.[61]

Rehabilitation

Early mobilization out of bed after hip fracture surgery is important for the general well-being of the patient; it reduces the risk of DVT, pulmonary complications, skin breakdown, and decline in mental status. Mobilization also inspires confidence and encourages the patient to recover. In addition to early mobilization and ambulation training, treatment goals for the physical therapist include patient training in transfers, improving strength, maintaining balance, and maintaining range of joint motion.

Ambulation training should be initiated on the first or second day after surgery. Most patients who have sustained a femoral neck fracture and were treated with either internal fixation or prosthetic replacement should be allowed to bear weight as tolerated. Elderly patients with decreased upper extremity strength and occasionally those with associated upper extremity fractures may find it difficult to comply with a non–weight-bearing or even a partial weight-bearing protocol. Another important consideration is that even partial weight bearing involves the generation of considerable force across the hip by the lower extremity musculature.[62]

Internal Fixation of Femoral Neck Fractures

Femoral neck fractures can be surgically treated by internal fixation or femoral head replacement. Impacted femoral neck fractures are usually treated by

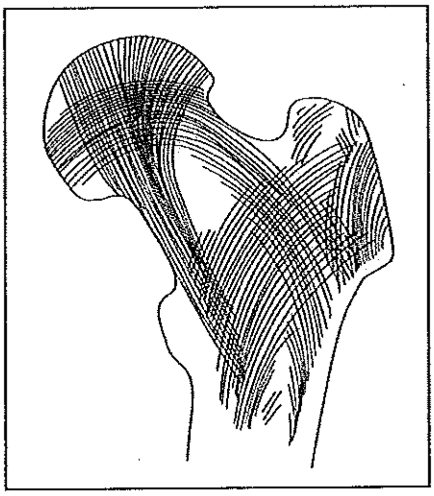

Figure 1 A trabecular network of bone supports the femoral neck and head. The center of the head, where the primary compressive and tension trabeculae coalesce, has the greatest density. The superior dome of the head has the second greatest density. (Reproduced with permission from Asnis SE, Kyle RF: Intracapsular hip fractures, in Asnis SE, Kyle RF (eds): *Cannulated Screw Fixation: Principles and Operative Techniques.* New York, NY, Springer-Verlag, 1996, p 52.)

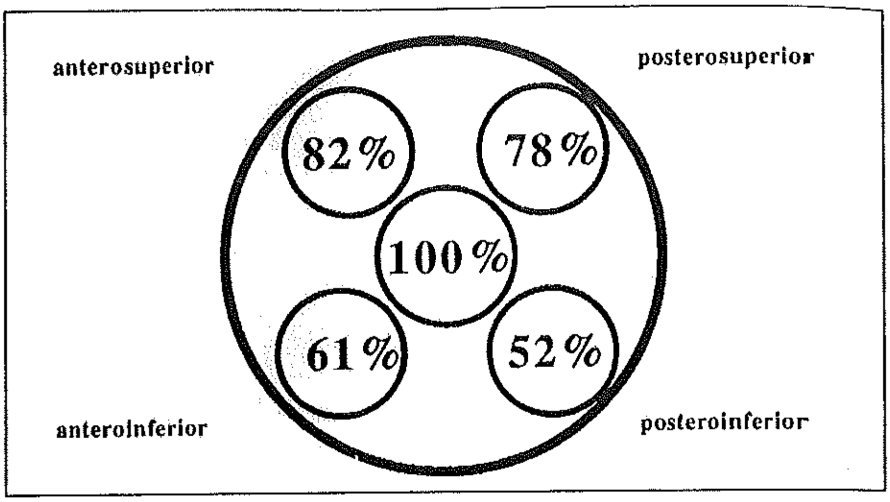

Figure 2 Bone density of cadaveric femoral heads. The middle and superior portions of the femoral head are more dense than the inferior portions.[69] (Reproduced with permission from Asnis SE, Kyle RF: Intracapsular hip fractures, in Asnis SE, Kyle RF (eds): *Cannulated Screw Fixation: Principles and Operative Techniques.* New York, NY, Springer-Verlag, 1996, p 52.)

internal fixation. The goal of this chapter is not to convince the surgeon to favor fixation, but rather when fixation is chosen, to do it properly. The quality of reduction and integrity of the newly constructed "bone-screw complex" can be significant. The quality of the bone, security of the bone-to-bone contact, number of screws, and position of the screws in the femoral neck and head all can be factors in obtaining osteosynthesis of the fracture and minimizing osteonecrosis.

Structural Anatomy and Aging

The male and female adult's neck-shaft angle is approximately 130° ± 7° and the femoral neck anteversion is 10° ± 7°.[63,64] The femoral head is slightly oblong[65] with an average size of 40 to 60 mm. The hip capsule is attached anteriorly at the intertrochanteric line, whereas posteriorly the lateral half of the femoral neck is extracapsular.[66] The portion of the neck that is intracapsular has no periosteum, and fractures must heal by endosteal union. In 1838, Ward[67] described a trabecular network that supported the femoral head and neck. The primary compression trabeculae concentrate at the medial femoral neck and then fan out under the superior dome of the femoral head (Figure 1). The primary tensile trabeculae make an arch from the fovea medially to the lateral femoral cortex just distal to the greater trochanter laterally. Secondary compressive and tensile trabeculae orient themselves according to Wolff's law to increase the structural strength. Singh and associates[68] found that with aging and osteopenia a progressive sequential loss of these trabeculae takes place, thus decreasing structural strength. The trochanteric and secondary compression and tensile trabeculae are lost first. As osteopenia continues, the primary tension trabeculae become interrupted and lost, followed last by the loss of primary compression trabeculae. Because those patients with intracapsular hip fractures usually represent a more osteopenic population, femoral head and neck bone density are most important in fixation. The trabecular bone within the femoral neck is often of very low density and is unable to support the fixation device alone, necessitating use of the femoral neck cortical bone for support. Bone density studies of cadaveric femoral heads have demonstrated that the bone in the middle and superior femoral head provides better support than the weaker bone of the inferior head[63,69] (Figure 2). These findings are consistent with those in studies assessing trabecular patterns. The densest bone is in the central head, whereas the posterior inferior quadrant is usually the weakest.[69]

The geometry of placement of fixation screws is determined by the anatomy of the femoral head and neck. The bone density within the femoral neck is typically very low, so that screws traversing the center of the femoral neck have very little support (as if they were in a hollow tube). Unlike a dynamic compression hip screw and sideplate, cannulated screw heads buttress against the femoral cortex and the threads lock in the femoral head. If forces are applied to direct the head fragment inferiorly or posteriorly and the screw shafts are apart from the endosteal

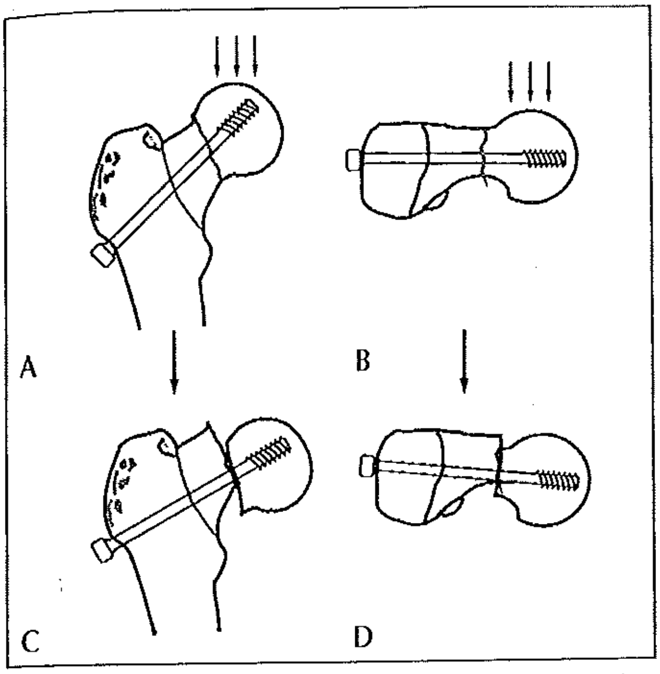

Figure 3 When forces are applied directly to the top of the femoral head in standing (A), the head fragment may fall inferiorly until the screw shaft rests on the medial femoral neck endocortex (B). Anterior forces on the femoral head, such as those applied when going from a sitting to standing position (C), can cause the head fragment to displace posteriorly until the screw shaft rests on the posterior femoral neck endocortex (D). (Reproduced with permission from Asnis SE, Kyle RF: Intracapsular hip fractures, in Asnis SE, Kyle RF (eds): *Cannulated Screw Fixation: Principles and Operative Techniques.* New York, NY, Springer-Verlag, 1996, p 53.)

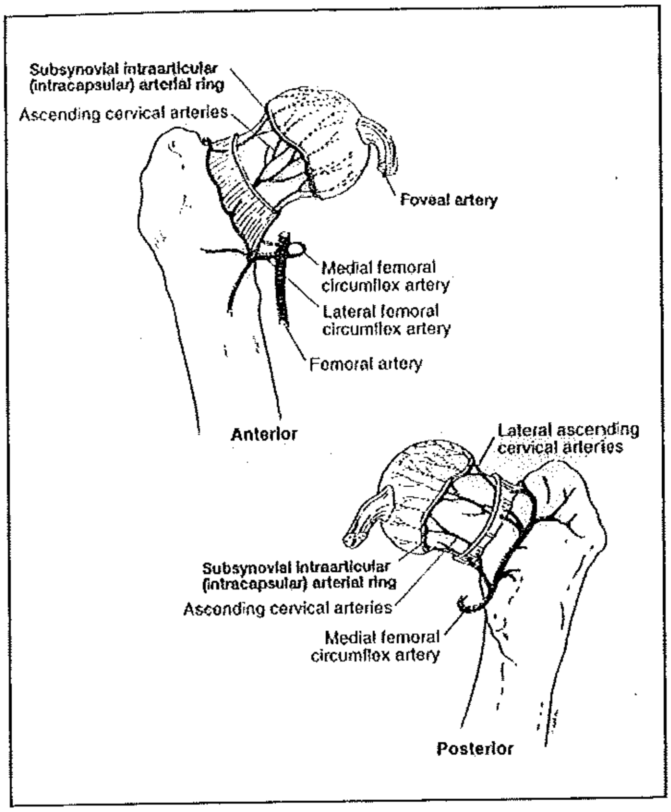

Figure 4 The arterial supply of the femoral head. (Reproduced with permission from Asnis SE, Kyle RF: Intracapsular hip fractures, in Asnis SE, Kyle RF (eds): *Cannulated Screw Fixation: Principles and Operative Techniques*. New York, NY, Springer-Verlag, 1996, p 54.)

cortical femoral neck, the femoral head and screws may drift until a screw's shaft comes to rest against the endosteal cortex[70,71] (Figure 3). Screw thread fixation in the head itself is dependent on the density of the trabecular bone; screw threads placed in the middle and superior head have better holding power than those in an inferior position.

Vascular Anatomy

Three major groups of vessels supply blood to the femoral head: (1) an extracapsular ring located at the base of the femoral neck; (2) ascending cervical branches on the surface of the femoral neck; and (3) arteries of the ligamentum teres, or foveal arteries[72,73] (Figure 4). A large branch of the medial circumflex artery posteriorly and branches of the lateral circumflex artery anteriorly form an extracapsular arterial ring at the base of the femoral neck. From this ring arise the ascending cervical branches that are anatomically described as the anterior, posterior, medial, and lateral groups. The lateral ascending cervical arteries appear to provide most of the blood supply to the superior femoral head and lateral neck. The ascending cervical vessels then go into a less distinct vascular ring at the articular cartilage-neck junction known as the subsynovial intra-articular arterial ring.[74] From this ring, vessels penetrate the femoral head and are then referred to as the epiphyseal arteries. The lateral epiphyseal artery is believed to supply most of the blood to the weight-bearing area of the femoral head. The lateral epiphyseal artery system passes within the posterior retinaculum of Weitbrecht.[73,75-78] More simply—and probably just as clinically relevant and accurate—Swiontkowski describes the lateral epiphyseal artery as the terminal branch of the medial circumflex artery supplying the weight-bearing surface of the femoral head in 90% of adults.[79] The terminal branch of the lateral circumflex artery supplies the inferior portion of the femoral head. The artery of the ligamentum teres is a branch of the obturator or medial circumflex artery. These vessels are believed to supply a substantial portion of the femoral head in only one third of patients.[80] However, these vessels may be important in revascularization of the femoral head after fixation. A very limited amount of blood is supplied through intraosseous vessels that come directly from the marrow below.

In a nondisplaced fracture, the risk of direct damage to epiphyseal arteries is far less. Bleeding into a capsule that has not been disrupted, however, may cause increased pressure and decreased blood supply by tamponade. The benefits of aspiration and capsulotomy during the procedure are still being debated, but may be beneficial in the patient with a nondisplaced fracture.[23,81-84] Significant intracapsular hematomas were not seen in a 1994 study of preoperative MRI of 20 patients with displaced fractures.[20] In the displaced fracture, a tear in the capsule may dissipate the hematoma. Instead, displaced fractures are likely to have direct arterial injury by disruption or kinking. The potential for vascular injury may be greater among Garden IV fractures than in Garden III fractures. The Garden IV fracture is believed to tear the posterior retinaculum of Weitbrecht and thus sustain a greater vascular insult. Early reduction and fixation may play a positive role by unkinking intact vessels, but this is still speculative.

Classification

Although several classification schemes exist for femoral neck fractures, the Garden classification will be discussed in this chapter. Garden's classification,[85-87] based on the degree of displacement of the fracture, is functional and appears to be the classification most widely used today. A Garden I fracture is an incomplete or an impacted fracture. A Garden II fracture is a complete fracture without displacement. A Garden III fracture is a complete fracture with displacement. The retinaculum of Weitbrecht remains intact and maintains continuity between the proximal and distal fragments. By being displaced and yet tethered by the retinaculum, the femoral head becomes tilted in the acetabulum and thus the trabecular pattern of the femoral head does not line up with that of the acetabulum. A Garden IV fracture is a completely displaced fracture with all continuity between the proximal and distal fragments disrupted. The femoral head can spin free, and its trabecular pattern usually lines up with that of the acetabulum. Many surgeons find it difficult to differentiate between Garden III and Garden IV fractures. In the Garden IV fracture, the femoral head may be rotated in the acetabulum because of the impingement of the distal fragment on the proximal fragment from the way the subject is positioned during the radiograph. Several surgeons have simply combined Garden I and II fractures into nondisplaced fractures and grouped Garden III and IV as displaced fractures.

The nondisplaced or Garden I and II fractures are fixed in situ. The valgus-impacted fractures are left in place and fixed. A capsulotomy may be considered for tamponade. Full weight bearing is permitted immediately after fixation. The incidence of nonunion is rare and because the vessels are intact, the occurrence of osteonecrosis should be low. The displaced or Garden III and IV fractures are expected to have a higher complication rate. Theoretically, the Garden III fracture has a better prognosis for two reasons. The posterior retinaculum of Weitbrecht is intact and the lateral epiphyseal artery system is more likely to be intact. A good reduction is also more readily obtainable. With the patient in traction and the posterior retinaculum intact, internal rotation reduces the fracture. The posterior retinaculum acts similar to the binding of a book as it is closed. Full weight bearing is generally permitted immediately after surgery if there is a good reduction with bone-to-bone support. Six weeks of partial weight bearing should be considered when the stability of the reduction or fixation is uncertain. Physical therapy is given for ambulation training, but range-of-motion exercises, particularly rotational exercises, should be avoided.

Treatment Controversy

In the displaced fracture in the elderly patient with osteoporosis, the decision between fixation and arthroplasty becomes an issue. Although prosthetic replacement is a more definitive mode of treatment, some studies have shown a higher morbidity and mortality rate than that for internal fixation.[88-92] In the more active individual, a hemiarthroplasty may require conversion to a total hip replacement.[93,94] Immediate total hip arthroplasty has been shown to have a far higher morbidity and mortality rate when done for an acute fracture than in the patient with chronic arthritis.[95,96] Franzen and associates[96] found the age- and sex-adjusted risk of prosthetic failure in total hip arthroplasties performed for femoral neck fracture complication to be 2.5 times higher than after primary arthroplasty performed for osteoarthritis ($P = 0.012$). Many other researchers have reported that the dislocation rate is significantly higher in fracture patients.[97-101] Nilsson and associates[101] compared one group of patients 4 to 12 years after a primary hemiarthroplasty with another group who had a secondary total hip replacement as a salvage procedure for complications of reduction and fixation of femoral neck fractures. The secondary total hip replacement group used walking aids to a lesser extent and experienced fewer problems in several aspects of life. The authors concluded that secondary total hip replacement in patients with healing complications following primary osteosynthesis provided better long-term functional capacity than that obtained with primary hemiarthroplasty.

Reduction and fixation of the intracapsular hip fracture with multiple pins or screws has been reported as a procedure of much lower morbidity and mortality than prosthetic arthroplasty.[88,91,92,102-104] With improved methods of fixation and a tendency toward earlier weight bearing, internal fixation becomes a more attractive mode of treatment—particularly in younger, more active patients. Those patients who develop the complication of nonunion or osteonecrosis can undergo total hip arthroplasty as a delayed elective procedure, with very low morbidity and mortality.[96,105]

Internal fixation of displaced intracapsular hip fractures is advantageous for many patients. Although statistics vary, it appears that the risk of death or major complication is lower following internal fixation than after immediate prosthetic replacement. For the 70% to 75% of patients whose fractures heal without subsequent development of osteonecrosis, their own femoral heads function as well as, or better than, prostheses. For those who have a problem with union or later develop osteonecrosis, a well-planned elective total hip arthroplasty is usually a safe procedure. The risks of medical complications appear far lower when the procedure is delayed rather than performed immediately after the fracture. The complications of internal fixation, namely osteonecrosis or nonunion, are much easier to deal with than complications of a failed hemiarthroplasty.

In the more active individual, a primary hemiarthroplasty does not perform as well as a total hip replacement. Primary total hip arthroplasty right after fracture has a higher complication rate and may not function as well as a delayed total hip procedure, which is required only in that group of patients who have complications after internal fixation.

Indications for Internal Fixation

The indication for cannulated screw fixation includes all nonpathologic nondisplaced or Garden I and II fractures. Age is not a factor. The displaced or Garden III and IV fractures can be treated by reduction and internal fixation or hemiarthroplasty or total hip arthroplasty. It is the authors' preference to perform reduction and fixation for all patients other than those in whom a primary prosthetic replacement is required. Prosthetic replacement is indicated for (1) failure to achieve a satisfactory reduction other than in the younger patient; (2) fracture of the femoral head or dislocation of the femoral head with fracture of the femoral neck; (3) fractures more than 5 days old; (4) pathologic fractures; (5) fractures in an abnormal hip, that is, the rheumatoid or osteoarthritic hip; (6) fractures with significant femoral neck comminution with a butterfly fragment of 1 cm or more; and (7) a Garden IV fracture in a patient older than 75 years and a Singh classification of III or less.

In the younger patient (younger than 55 years), all attempts are made to obtain a satisfactory reduction. If this is not possible or there is posterior neck comminution, then open reduction and a bone grafting procedure should be considered.[106]

Potential Complications of Internal Fixation

Problems in Healing Multiple cannulated parallel screws were introduced for the fixation of femoral neck fractures in 1980 in an attempt to increase the accuracy of fixation and decrease complications.[107-109] Although it appears that the rate of successful osteosynthesis has improved significantly with this technique, the incidence of osteonecrosis may be unchanged. In a long-term follow-up study of 141 patients treated with cannulated screws, only 5 had a loss of position or nonunion;[108] this resulted in a 96% chance of successful osteosynthesis. However, internal fixation of the displaced femoral neck fracture is not a simple procedure. A stable reduction is essential and the fixation screws must be placed accurately.

Osteonecrosis Osteonecrosis remains the main complication following internal fixation of femoral neck fractures. A displaced femoral neck fracture has a devastating effect on the blood supply of the femoral head. Following autoradiograms of femoral head specimens of patients given phosphorus 32(P32) before prosthetic arthroplasty for acute femoral neck fractures, Calandruccio and Anderson[110] reported that 22% of the femoral heads were completely vascular, 32% were completely avascular, and 47% were partially avascular. Catto's[111,112] meticulous histologic studies of whole femoral heads obtained at least 16 days after transcervical fracture showed 34% of the femoral heads to be completely vascular, 55% partially avascular, and 11% totally avascular. Sevitt's[113] arteriographic and histologic necropsy of the femoral heads with femoral neck fractures showed total or partial necrosis in 84% of the specimens. Apparently, most patients sustain a significant vascular injury at the time of the fracture, yet only 20% to 30% of patients who undergo internal fixation develop radiographic evidence of osteonecrosis with clinical segmental collapse. Most displaced femoral neck fractures probably undergo significant revascularization following internal fixation. During this period, the fracture heals and most patients function well even though a significant area of the femoral head may still be partially avascular. Many of the original studies on femoral neck fractures gave rates of osteonecrosis based on the false assumption that most segmental collapse would be evident by 2 years. However, it appears that revascularization for the femoral head is a very slow process and in some patients is never complete. In one long-term follow-up study of 141 patients treated with cannulated screws, a 9% rate of osteonecrosis at 2 years was followed by an overall 18% incidence after an average follow-up of 8 years (minimum follow-up 5 years); 3 of the patients first developed clinical symptoms and segmental collapse after 5 years.[104] Although segmental collapse may develop long after the initial fracture, function of the patient is the prima-

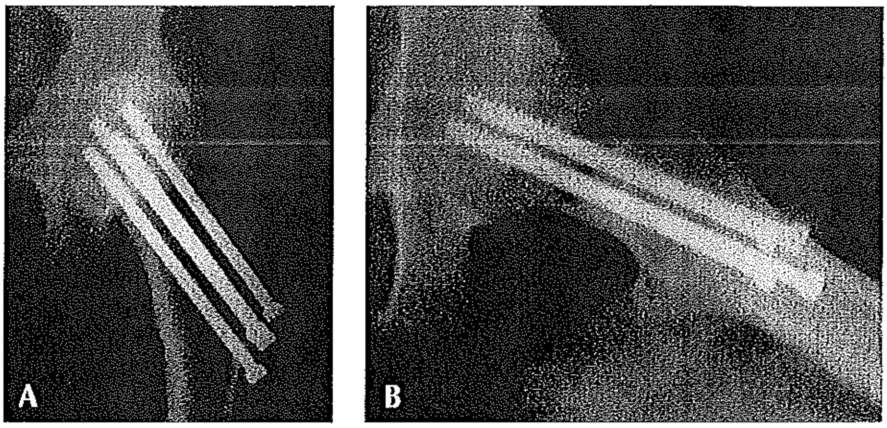

Figure 5 Fixation of a femoral neck fracture with four parallel 6.5-mm screws in a diamond configuration. **A,** The AP radiograph shows the head well supported by the femoral neck. The stable "hat hook" position with the impaction of the superior femoral neck beneath the subchondral bone of the superior femoral head is shown. The most distal screw shaft lies along the medial neck, preventing the femoral head from falling into varus. **B,** The posterior screw shaft lies along the posterior femoral neck, preventing the femoral head from displacing posteriorly.

ry goal of treatment. Many patients have excellent function and no symptoms even though the femoral head is partially avascular. Frequently, symptoms appear only after the ultimate development of segmental collapse. Once symptoms do appear, elective total hip arthroplasty appears safe and extremely effective, with results equivalent to those of total hip replacement in patients with primary osteoarthritis.

Reduction

The most important objective in the treatment of the displaced femoral neck fracture is to obtain stable bony support of the femoral head on the femoral neck. The fixation is used to increase stability by compressing the fracture and then maintaining the reduction by neutralizing forces acting on the hip. Even if a patient is not bearing weight, going from a sitting to a standing position creates three times as much force across the hip as does weight bearing.[114] The factors that decrease stability are comminution of the posterior femoral neck and poor reduction.[115] Major comminution of the femoral neck is a contraindication for reduction and fixation, and hemiarthroplasty usually becomes the preferred treatment; however, as stated earlier, in the younger patient an open reduction and bone graft should be considered.[106]

The Garden Index is an expression of the angle of the compression trabeculae on the AP radiograph over the angle of the compression trabeculae on the lateral radiograph. A perfect anatomic reduction is therefore expressed as 160/180. Thus, the goal of reduction is a position as close as possible to a Garden Index of 160/180 (AP/lateral).[85-87] On the AP radiograph, the primary compression trabeculae should ideally be at an angle of 160° to the longitudinal axis of the femoral shaft, whereas on the lateral radiograph these compression trabeculae should lie in a straight line or 180° with the femoral shaft axis. In a good reduction, the medial femoral head and neck fragment are well supported by the medial neck of the femur. The position should be either anatomic or with the head and neck fragment in slight lateral translation in relation to the supporting femoral neck. Although slight valgus is acceptable, varus is not. Slight valgus with the superior femoral neck impacted beneath the subchondral bone of the superior femoral head usually provides a very stable configuration.[64] This acts as a "hat hook" and transforms the downward force of the body weight onto the femoral head into a force that enhances compression of the fracture (Figure 5). On the lateral view, alignment is again important, with the posterior neck of the distal fragment supporting that of the head and neck fragment.[116]

Reduction can be accomplished with traction on a fracture table with the leg in neutral flexion, neutral rotation, and 10° of abduction. The leg is then internally rotated as far as possible, and then backed off into a position of 15° of internal rotation. The medial neck spike of the fragment should be well supported by the femoral neck of the femur. With a cannulated screw system, some overdistraction at the time of the initial reduction is permissible because the fracture can later be guided into a good position and compressed once the parallel guide pins are in place or with the lag of the parallel screws. In most patients without major femoral neck comminution, this maneuver will yield a satisfactory and stable position. In very rare instances, an open reduction may be necessary before fixation.

Fixation Screws

The purposes of the fixation screws are to (1) lock the fracture in a position in which the femoral neck gives bone-against-bone support to the femoral head-neck fragment; (2) prevent posterior and varus migration of the femoral head; and (3) be parallel in order to maintain bone-on-bone support as the fracture settles in the healing period. In a cannulated screw system, the smaller diameter guide pins can be used to accurately determine the screw position as well as the length, and the accuracy of screw placement is improved with jigs for placement of guide pins. With parallel screws, excellent compression can be produced atraumatically by the lag effect of the screws.

Geometry of Screw Position in the Femoral Neck and Head

To prevent femoral head migration, screw positioning is critical. The most distal single screw passes through the femoral cortex, with its shaft resting on the supporting medial neck, and its threads fixing the inferior femoral head (Figure 6). For the femoral head to fall into varus, this screw's threads must first cut through the femoral head. In the lateral plane, a second screw should be placed posteriorly so that it rests on the posterior neck of the distal fragment at the midhead level on the AP plane. For posterior head migration to occur, its threads must cut through the head (Figure 6). The positioning of these two screws is crucial. Martens and associates[70] demonstrated that internal fixation using multiple Knowles pins had a high rate of failure unless the most distal screw rested on the cortical bone of the medial aspect of the femoral neck (Figure 3). Lindequist[71] evaluated 87 patients who had internal fixation of femoral neck fractures with two von Bahr screws. He found that the posterior placement of the proximal screw and the inferior placement of the distal screw improved the rate of fracture union. Studies in Sweden using fixation with only two hooked pins in these key locations gave fair clinical results.[117,118]

Deyerle[119] found that multiple pins placed around the periphery of the femoral neck compressing the fracture provided rotatory stability. Three or four parallel cannulated screws placed peripherally around the femoral neck compressing the fracture are equally atraumatic and also yield excellent rotatory stability.

Following these principles, it is the authors' preference to place two screws—the first along the endocortex of the femoral neck in the distal position and then the second along the endocortex in the posterior position. In Garden I and II fractures, a third screw at the midhead level on the AP view and in an anterior position on the lateral view provides additional stability (Figures 7, *A*, and 8). In the Garden III and IV fractures, a fourth screw superiorly on the AP view and midline in the lateral view further supplements fixation (Figures 5 and 7, *B*). Studies by Swiontkowski and associates[120] and Springer and associates[121] have suggested that the fourth screw added little in additional fixation; however, both of these teams used models that represented a Garden II fracture and not the Garden III or IV fracture with some comminution. In a biomechanical study conducted in 1999 by Kauffman and

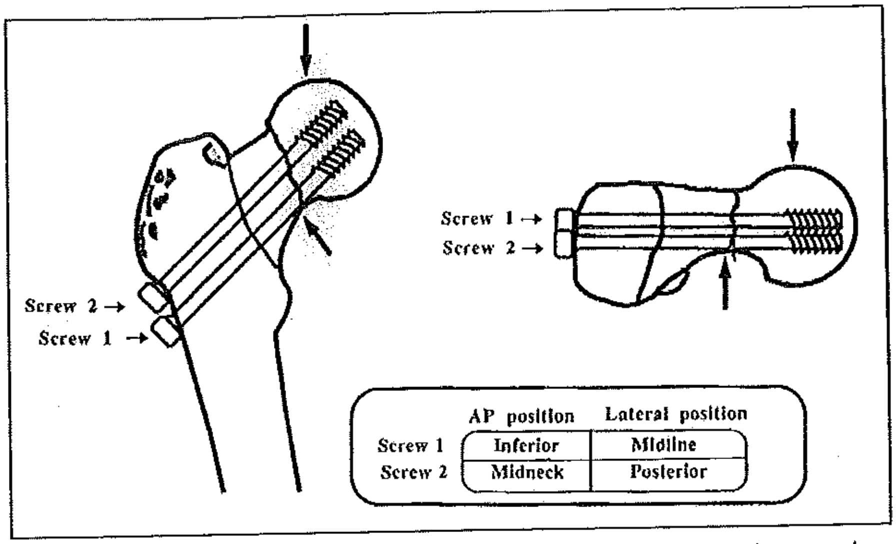

Figure 6 Screw positioning. In the AP plane, the most distal screw shaft (screw 1) rests on the medial femoral neck. A second screw (screw 2) should be at the midhead level on the AP projection and should rest on the posterior femoral neck in the lateral plane. (Reproduced with permission from Asnis SE, Kyle RF: Intracapsular hip fractures, in Asnis SE, Kyle RF (eds): *Cannulated Screw Fixation: Principles and Operative Techniques*. New York, NY, Springer-Verlag, 1996, p 60.)

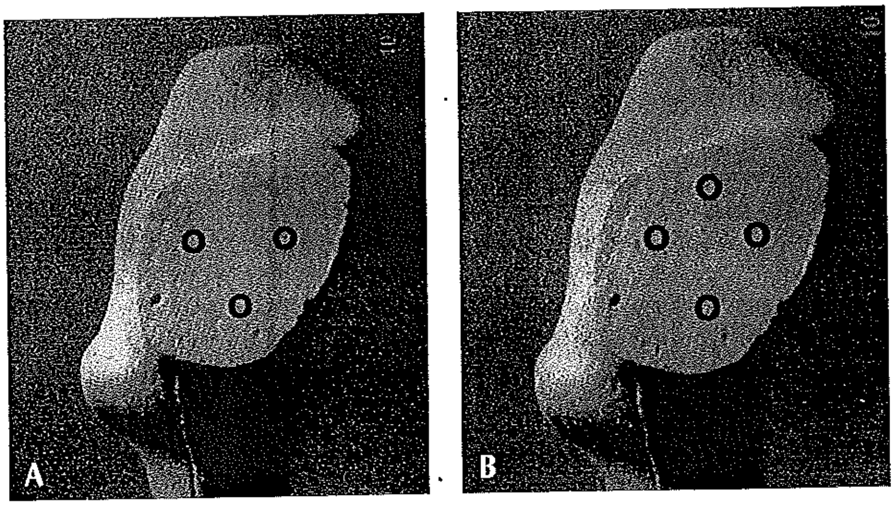

Figure 7 Cross-section showing the position of the screws in the femoral neck. **A,** Three-screw inverted triangle configuration. **B,** Four-screw diamond configuration.

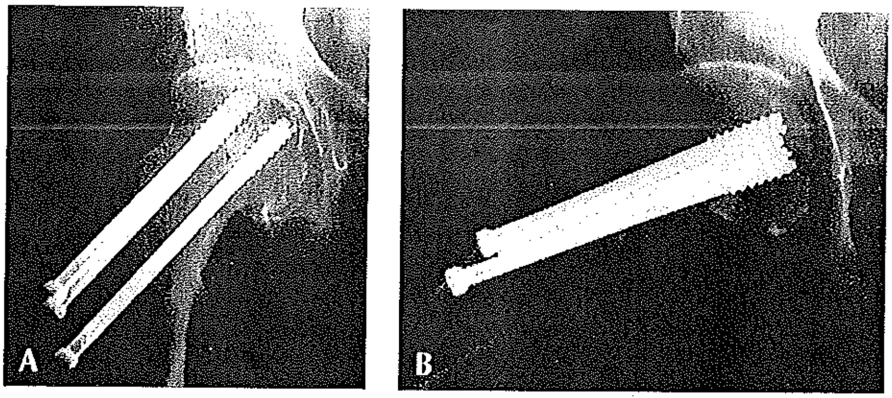

Figure 8 Fixation of an femoral neck fracture with three parallel 6.5-mm screws in an inverted triangle configuration. **A**, The AP radiograph shows the most distal screw shaft resting on the medial neck. The proximal two screws are placed slightly above the midhead level. **B**, The posterior screw shaft lies along the posterior femoral neck.

associates,[122] the fourth screw was shown to add significant fixation.[108,109]

The inverted triangle and diamond patterns of screw placement also fit well into the shape of the femoral neck (Figure 7). Although most mechanical models show the head loaded in the standing position, studies have shown that the hip bears three times the force when going from sitting to standing than when walking.[114] The triangle and diamond patterns adapt well to the different forces applied to the hip in different body positions.

The distal screw should not enter the femoral cortex below the level of the lesser trochanter. No more than one screw hole (either with a screw present or left empty) should ever be made at the level of the lesser trochanter. Because there is no sideplate, weakness at this level can lead to a subtrochanteric fracture.[123] Two distal screws at the level of or distal to the lesser trochanter must be used with caution. Iatrogenic fractures can occur at this level, propagating from a crack between the distal holes. No subtrochanteric fractures occurred in one series of 141 patients.[108]

Femoral Head Bone Density and Fixation Geometry

Fixation of the femoral head is also dependent on the holding power of the screw threads in the trabecular bone of the femoral head. Crowell and associates[69] and Benterud and associates[63] designed screw pull-out models in which they found the previous recommendations of screw placement in the inferior and posteromedial portions of the femoral head for better stability to be incorrect. In each of these studies, screws were placed in different quadrants of femoral heads collected at autopsy and pull-out tests were performed. The inferior portions of the femoral heads were consistently less dense, with significantly lower screw pull-out strength ($P < 0.05$). The increased trabecular density of the central and superior femoral head gave far better fixation (Figure 2). Evidence of better fixation was noted in patient radiographs. The center of the head, where the tension and compression trabeculae both pass, appears most dense, followed by the compression trabeculae in the superior femoral head. In a fracture patient with osteoporosis and/or osteopenia, the inferior head often clearly demonstrates the lack of trabeculae and minimal cancellous bone density. The data strongly favor the inverted triangle and diamond patterns for improved fixation.

Preferred Surgical Technique: Parallel Cannulated Screws

The authors' preference is a system using a 3.2-mm guide pin and a cannulated 6.5-mm self-tapping screw.[107,109] The 3.2-mm guide pin is stiff enough not to bend easily and can reliably be used through guide jigs. The 6.5-mm screw with a 20-mm threaded tip has very good holding power, and the 20-mm thread does not go across the fracture site as can happen with longer thread lengths.

The patient is placed in a supine position on a fracture table. If the fracture is displaced, traction is applied with the leg in neutral flexion, 10° of abduction, and neutral rotation. The leg is then internally rotated as far as possible with moderate force, and then backed off to a position of 15° of internal rotation. The reduction is confirmed by fluoroscopy. If satisfactory alignment but some distraction is present, the internal fixation is performed and the fracture impacted with the parallel guide pins in place or with the lag of the screws.

A 6-cm straight lateral incision is made, starting at the flare of the greater trochanter and extending distally. The fascia lata and fascia of the vastus lateralis are cut in line with the incision and the vastus lateralis is bluntly split. The lateral femoral cortex is visualized. A percutaneous procedure can be used, but in this procedure there is probably as much soft-tissue trauma beneath the skin as that of a small muscle-splitting approach. The open procedure provides the added advantage of direct visualization of the lateral femoral cortex so that the cortical bone entrance holes can be more precise. The cortex can also be visualized as the screws are tightened and the head buttresses against the bone with compression.

The most distal guide pin is placed first. A drill hole is made with a 3.2-mm drill 3 cm to 4 cm distal to the vastus externus tubercle, usually at the level of the lesser trochanter, and midway between the anterior and posterior femoral cortices. This is the only hole that is predrilled for the guide pin because the cortex may be very dense at this location.

The 3.2-mm guide pin is then passed through this hole, along (and almost resting on) the medial femoral neck, across the fracture, and into the femoral head. On the lateral view, this pin should stay in the midline of the femoral neck and head. Pin position is confirmed by fluoroscopy. If a correction is to be made, use of the same cortical hole is attempted. Extra holes at this level of the femoral shaft may weaken the femur at the subtrochanteric level.

A fixed guide with a selection of triangles or diamonds is then selected (Figure 9). The appropriate sized diamond or triangle can be determined with preoperative radiograph stenciling. If there is a question between two sizes, the smaller pattern is used. The use of three screws in an inverted triangle configuration is preferred for Garden I and II fractures, and four screws in a diamond configuration for a Garden III or IV fracture. The fixed jig is placed over the already positioned guide pin, and the remaining two or three guide pins are placed (Figures 10 and 11). These guide pins are driven by power directly through the cortex, up the femoral neck, and into the femoral head. Predrilling is usually not necessary.

The direct reading depth gauge is then used to determine screw length. If the measured length is between sizes, the shorter length is used. If the fracture is to be compressed, a screw 5 mm to 10 mm shorter than measured is chosen. This will leave room for the threads to advance in the femoral head as the screw lags and the fracture compresses.

The self-cutting/tapping cannulated screw of the selected length is then placed over its guide pin and driven through the cortex and across the fracture with the cannulated power screwdriver. When the head is 10 mm from the femoral cortex, the power driver is removed. The screw is then driven the remainder of its path with the hand screwdriver (Figure 12). The remaining screws are placed and the guide pins removed. Compression can be obtained by gently tightening the screws (Figure 13). When the screws are tightened, occasionally the inferior screw will spin in the osteoporotic patient because the bone in the inferior head is the weakest. The remaining screws in the middle and upper portions of the head will achieve excellent hold of the femoral head. The lower screw will still deter inferior motion of the head fragment as the screw rests on the endosteum of the femoral neck.

When a screw is removed after fracture healing, the screw thread must recut its way through the healed femoral cortex. Many types of cannulated screws have reverse cutting flutes for this purpose. If the oblique angle (approximately 135°) of the screw to the femoral shaft is not changed, the reverse cutting flutes are not in an optimal position to cut into the cortex. When the thread meets the endocortex, the screw can be pulled into a perpendicular position to the bone with a screwhead retractor, thus permitting the reverse cutting flutes to position themselves properly and facilitate screw removal. A worn or damaged screwdriver should never be used because of the danger of stripping the recess socket.

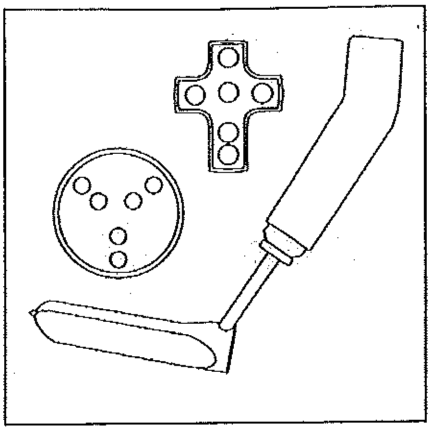

Figure 9 Fixed guides for the triangle or diamond patterns. (Courtesy of Stryker Howmedica Osteonics, Allendale, NJ.)

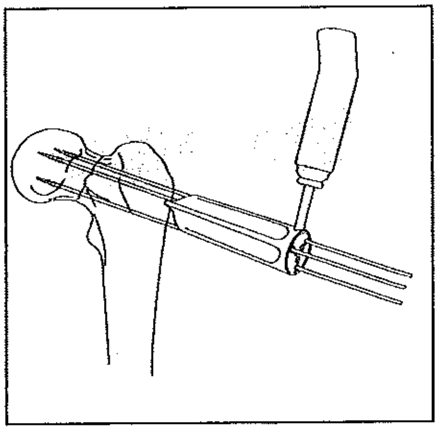

Figure 10 AP projection of the placement of three parallel guide pins. (Courtesy of Stryker Howmedica Osteonics, Allendale, NJ.)

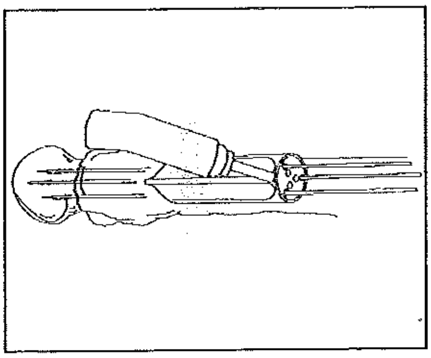

Figure 11 Lateral projection of three parallel guide pins. (Courtesy of Stryker Howmedica Osteonics, Allendale, NJ.)

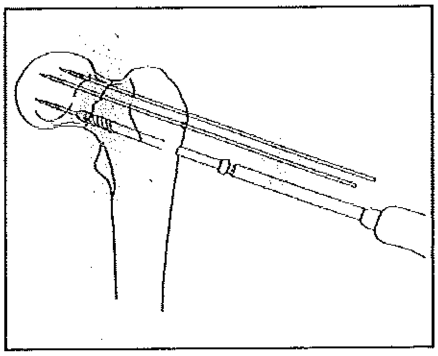

Figure 12 The 6.5-mm cannulated screws of appropriate length are passed over the guide pins. (Courtesy of Stryker Howmedica Osteonics, Allendale, NJ.)

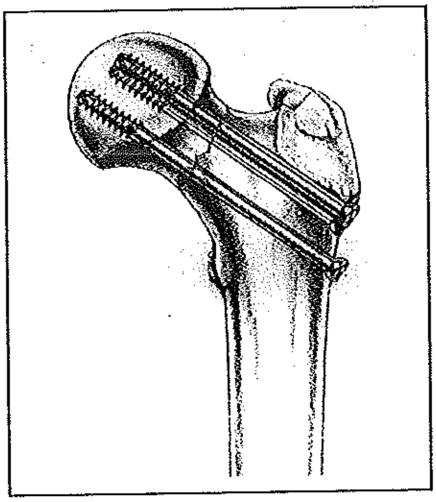

Figure 13 The cannulated screws are placed, the fracture compressed by gently tightening the screws, and the guide pins are removed. (Courtesy of Stryker Howmedica Osteonics, Allendale, NJ.)

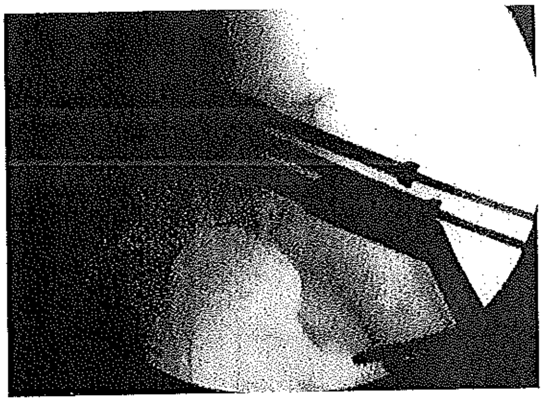

Figure 14 A dynamic hip compression screw and sideplate can be used with one or two derotational screws. The guide pins are placed before inserting the dynamic hip compression screw bolt. After the dynamic hip compression screw and sideplate are applied, cannulated screws are place over their guide pins and the pins removed.

Dynamic Hip Compression and a Parallel Derotational Cannulated Screw

An alternate method of fixation uses a dynamic hip compression screw with a two-hole sideplate. On occasion, when additional fixation may be required (for example, in a patient with Parkinson's disease or certain neurologic disorders), a dynamic hip compression screw and two-hole sideplate is used. The hip is reduced on the fracture table and the dynamic hip compression screw guide pin is placed, followed by one or two guide pins from the 6.5-mm cannulated screw set. The bolt is placed in the center of the femoral head or slightly distal to allow room for the derotational screws. Enough distance is left between the guide pins to allow room for the cannulated screw heads to clear the dynamic hip compression screw plate proximally on the lateral femoral shaft. The derotational guide pins stabilize the head fragment to prevent rotation during the reaming, taping, and placement of the dynamic hip compression screw bolt. After the sideplate of the dynamic hip compression screw is added and compression applied, the depth gauge is used over the guide pins of the cannulated screw system. The appropriate cannulated screw length is chosen and the screws are placed (Figure 14).

Clinical Results of a Long-Term Follow-up of Parallel Cannulated Screws for Femoral Neck Fractures

In one retrospective study of the results of stabilizing nonpathologic femoral neck fractures with parallel cannulated screws from 1980 through 1985,[103] 50 of the 141 patients (35%) had nondisplaced fractures (Garden I and II), whereas 91 (65%) had displaced fractures (Garden III and IV). The median age was 68 years (range, 24 to 95 years). There were 112 white females (79%) with a median age of 67 years (range, 30 to 90 years) at the time of fracture and 29 white males (21%) with a median age of 69 years (range, 24 to 95 years). The proportion of displaced and nondisplaced fractures was approximately equal by gender and side of fracture. No deaths or wound infections occurred during the fracture hospitalization, and the mean follow-up was 8 years.

Eleven patients, six males and five females (median age, 75 years), died within the first year after surgery. Twenty-nine patients (median age, 75 years) died within 5 years. Fifty percent of the entire group of patients had at least one major concomitant medical disease. Of the 29 patients who died, only three had no major initial medical disorder. Mortality was related more to the medical condition of the patient than to the fracture episode itself. The mortality rate of this patient group was compared with a control cohort group matched for age, sex, and race. This group was from the population at large and medical illness was not taken into consideration. The survival curve of the cohort group remained within the 95% confidence interval limit of the fracture group for the entire length of the study (Figure 15). Although a trend of increased mortality existed for the first 2 years following fracture, this was not significant. The men and women were separated and compared with each other as well as each with their own control cohort group. The female patients' survival curve followed that of their control cohort group. The survival curve for the males shows a much poorer prognosis than the females ($P < 0.0001$) (Figure 16), and the survival curve for the male patients was significantly poorer than that of their control cohort group.

Five of the 141 patients (4%)—two with Garden III and three with Garden IV fractures—experienced a loss of position or nonunion by 6 months after surgery. All five patients were women. Two of the five patients underwent total hip replacement, and one had a hemiarthroplasty.

Thirteen patients (9%) were found to have histologic or radiographic evidence of osteonecrosis within 2 years of treatment. Ten of these patients had initially displaced fractures. Another 13 cases of osteonecrosis were diagnosed after 2 years; 8 were initially displaced fractures. Twenty-five of the 26 osteonecrosis patients were females. Four of them first developed segmental collapse 5 to 8 years after their fracture. The prevalence of osteonecrosis was therefore 18% with a mean follow-up of 8 years. Osteonecrosis was present in 8 of 39 patients with a Garden II, 6 of 30 patients with a Garden III, and 12 of 40 patients with a Garden IV fracture. Sixteen of the 26 patients with osteonecrosis underwent a total hip replacement at a mean of 2 years following their fracture.

By a minimum 5-year follow-up, 30 patients were lost to follow-up. In 55 patients, fracture healing was free of complications and the patients were found to be functioning well after 5 years (average follow-up 8 years). Using Kaplan-Meier survival rates, this study demonstrated greater than 71% implant survival 7 years following the fracture (Figure 17). Forty-four of these patients had an average Harris Hip Score of 94 (range, 58 to 100) from 5 to 11 years after their procedure.

Multiple cannulated screw fixation represents a procedure with low surgical mortality and morbidity and a very high rate of fracture union (96%). An increased mortality rate was found for the male patients; however, this appeared to be related to the concomitant medical disorders rather than the surgery. The male patient has a poorer survival rate following hip fracture than the female patient. Osteonecrosis remains the major surgical complication following the fixation of the femoral neck fracture and can continue to present itself years after fracture healing. The female patient has a far higher incidence of nonunion or osteonecrosis than the male patient.

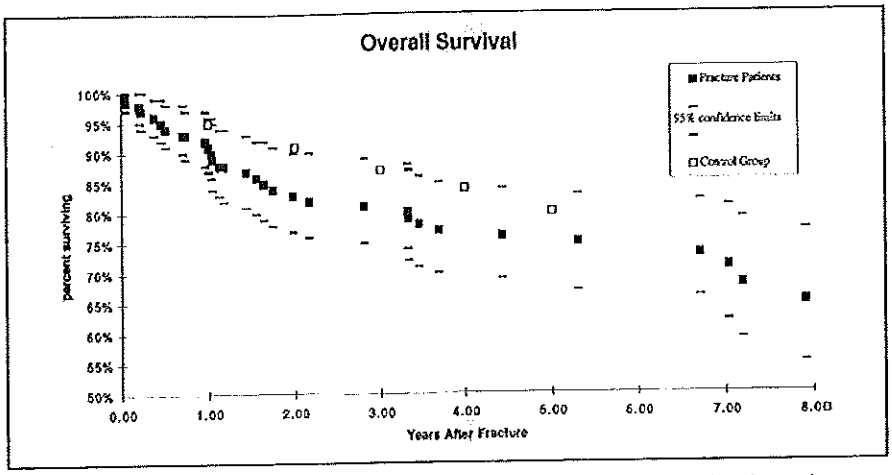

Figure 15 The overall survival curve for the fracture patient group compared with a cohort group matched for age, sex, and race. (Reproduced with permission from Asnis SE, Wanek-Sgaglione L: Intracapsular fractures of femoral neck: Results of cannulated screw fixation. *J Bone Joint Surg Am* 1994;76:1793-1803.)

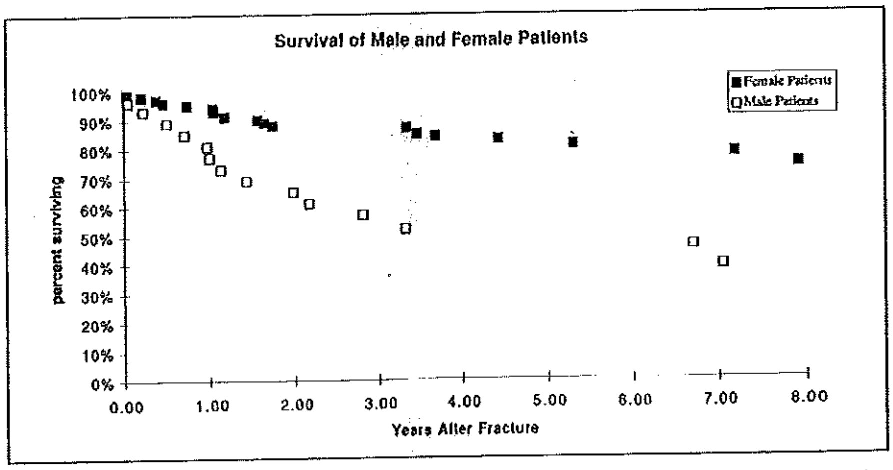

Figure 16 The survival curve following femoral neck fracture shows a much poorer prognosis for the male patients than the female patients. (Reproduced with permission from Asnis SE, Wanek-Sgaglione L: Intracapsular fractures of femoral neck: Results of cannulated screw fixation. *J Bone Joint Surg Am* 1994;76:1793-1803.)

Segmental collapse can be treated with a well-planned elective total hip replacement at a medically safer time. Those patients in whom the fracture heals without osteonecrosis maintain excellent function long after their injury.

Arthroplasty Options for Femoral Neck Fractures

Much controversy surrounds decision making regarding hip arthroplasty for the treatment of acute displaced femoral neck fractures. Controversial topics include the decision as to when prosthetic replacement instead of open reduction and internal fixation is appropriate, which type of prosthesis to choose (monopolar, bipolar, or total hip arthroplasty), and the method of prosthetic fixation (cemented or cementless). This section will review the indications, results, and potential complications of

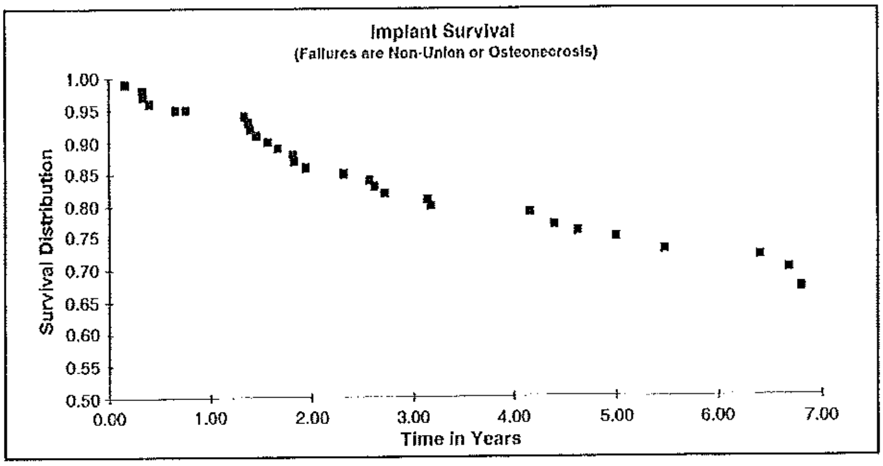

Figure 17 The implant survival rate defines a successful screw fixation as one functioning well or that functioned well until the death of a patient. A failure is defined as either a failure of fixation, failure to heal satisfactorily, or development of osteonecrosis. This study demonstrated 71% implant survival 7 years following the fracture. (Reproduced with permission from Asnis SE, Wanek-Sgaglione L: Intracapsular fractures of femoral neck: Results of cannulated screw fixation. *J Bone Joint Surg Am* 1994;76:1793-1803.)

prosthetic replacement for the treatment of acute displaced femoral neck fracture.

Justification for Prosthetic Replacement

Many older patients may benefit from an attempt at internal fixation.[124,125] Chronologic age alone should not be the only factor considered when determining the best therapeutic option for the patient with a displaced femoral neck fracture. Robinson and associates[9] recommended a protocol wherein all patients younger than 65 years or those with nondisplaced fractures were treated with internal fixation. Patients older than 85 years were treated with hemiarthroplasty. For those between 65 and 85 years of age, decision making was individualized, taking into account activity, general health, cognitive status, and bone quality compiled into a "physiologic score." Revision was necessary in only 5% of patients. This study underscores the importance of individualizing treatment methods rather than simply using chronologic age. Other authors have identified certain fracture characteristics such as fracture verticality, perceived difficulty of reduction, or varus reduction as predictive of fixation failure.[126-129] Although many surgeons still favor an attempt at open reduction and internal fixation[103] and reserve arthroplasty for fixation failure, a recent study by McKinley and Robinson[130] documented better outcomes for primary arthroplasty than for arthroplasty performed after fixation failure. Multiple studies have demonstrated hip arthroplasty to be an effective method of salvage of fixation failure.[96,101,131-135]

Many factors contribute to the justification for primary prosthetic replacement over an internal fixation attempt in elderly patients with acute displaced femoral neck fractures. These patients typically have low functional demands, poor medical health, and osteopenia. Many patients can have associated neurologic disease (mild dementia, Parkinson's disease, or sequelae of a previous cerebrovascular accident) and therefore need to be mobilized quickly with a single predictable procedure that carries a low rate of failure and revision. Several challenges face the surgeon attempting successful internal fixation of a displaced femoral neck fracture in the elderly patient. The main limiting factor to the success of any construct, of course, is the bone quality in the proximal fragment. These fractures can be comminuted and have vertical fracture lines and extremely osteopenic bone; this renders predictable, stable internal fixation of the proximal fragment difficult, if not impossible.

Several retrospective and prospective studies have compared open reduction and internal fixation to primary prosthetic replacement for displaced femoral neck fractures in elderly patients.[125,136,13 Soreide and associates[138] compared oper reduction and internal fixation to prosthetic replacement in a prospective, randomized study. Patients treated with prosthetic replacement had fewer complications and better hip scores. Sikorsk and Barrington[139] prospectively studiec 218 patients older than 70 years treatec by three methods: open reduction anc internal fixation, cemented hemiarthroplasty through an anterolateral approach and a cemented hemiarthroplasty througl a posterolateral approach. Mortality rate were lower for patients treated througl the anterior approach. The technica results were worse with open reductioi and internal fixation. Bray and associ ates[140] compared internal fixation to pri mary bipolar hemiarthroplasty in prospective, randomized comparison anc found that patients treated with prosthe ses had less pain, fewer complications and greater mobility. In a large meta analysis of displaced femoral neck frac tures in elderly patients, Lu-Yao and asso ciates[3] found an overall nonunion rate o 33% with internal fixation in this cohor and osteonecrosis in 16%. The nee for revision was found to be 20% to 36 for those patients treated with intern fixation versus 6% to 18% for thos treated with arthroplasty. They demon strated a 66% decrease in the risk c revision with arthroplasty. In a mor recent meta-analysis comparing ope reduction and internal fixation with arthroplasty for displaced femoral neck fractures, Bhandari and associates[141] found that arthroplasty reduced the risk of revision by 77%. However, arthroplasty was associated with more blood loss, longer surgical times, more infections, and greater early mortality.[141] Ravikumar and Marsh[7] randomized 290 patients age 65 years and older to receive treatment with internal fixation, hemiarthroplasty, or total hip arthroplasty. Open reduction and internal fixation demonstrated a 33% rate of revision. There was no difference in mortality between those patients treated with arthroplasty and those treated with internal fixation. Johansson and associates[142] randomized 100 patients age 75 years and older with displaced fractures to undergo either open reduction and internal fixation with two screws or total hip arthroplasty. There was no increase in morbidity or mortality in patients treated with arthroplasty. Functional scores were better with total hip arthroplasty. Finally, Rogmark and associates[143] randomized 409 patients older than 70 years to undergo either internal fixation or arthroplasty. After a mean follow-up of 2 years, treatment with internal fixation failed in 43%, whereas arthroplasty treatment failed in only 6%. Of particular importance, there was no difference in mortality between the two groups, and function was generally better with arthroplasty.

For displaced acute femoral neck fractures in elderly patients, arthroplasty offers lower revision rates, generally better function, and no clear increase in morbidity or mortality compared with patients treated with internal fixation. Despite contemporary methods of internal fixation, failure rates of approximately 30% to 40% continue to be consistently reported in the literature. Because internal fixation in this elderly cohort remains unpredictable, primary prosthetic replacement may, in fact, be the treatment of choice for this cohort.

Hemiarthroplasty: General Considerations and Fixation Options

In the United States, hemiarthroplasty has been the traditional treatment of displaced femoral neck fractures in elderly patients because of predictably lower revision rates, a relatively low complication rate, and reasonable function.[89,144-159] Most patients with a displaced femoral neck fracture have normal acetabular cartilage. Additionally, dislocation rates for hemiarthroplasty in general have been approximately 2% or lower, which is much lower than rates reported across several studies for total hip arthroplasty.[160-162] When determining the ideal hemiarthroplasty implant type for each patient, factors such as bone quality, age, and activity level must be individualized, and other potential comorbidities that may make the use of cemented fixation hazardous must be taken into account. First-generation one-piece cementless hemiarthroplasties of the Austin-Moore type should be reserved for the most minimally ambulatory or nonambulatory patients, such as those with severe dementia or prohibitive medical comorbidities. These designs probably function more as spacers, and it is unlikely that they ever achieve enough bony stability to allow prolonged pain-free ambulation. Concerning rates of acetabular erosion and revision have been reported when these designs have been used in active patients.[163-166] Newer designs offer improved metaphyseal geometries allowing fit and fill of the proximal femur and provide modularity to facilitate better restoration of leg length and soft-tissue balancing. Data on the performance of these designs, however, are lacking. Lu-Yao and associates[3] noted that cemented hemiarthroplasty has demonstrated functional results superior to cementless hemiarthroplasty.[167] This is not surprising because cement offers immediate secure fixation in bones that are often capacious and osteopenic.[168] However, the major concern when performing cemented arthroplasty in this setting is the fact that these patients are frail and may have multiple cardiopulmonary comorbidities and therefore less "reserve." Embolization of the typically fatty marrow contents that are found in large femoral canals can lead to intraoperative hemodynamic instability caused by embolization. Parvizi and associates[169] recently reviewed the intraoperative mortality during hip arthroplasty. Of the 23 patients who died during surgery, 13 were being treated for acute hip fractures, and all died during the cementation process. Bone marrow microemboli were found on autopsy in the pulmonary vasculature. Ereth and associates[170] and Esemenli and associates[171] reported on a "bone-cement implantation syndrome" consisting of hypotension, hypoxemia, arrhythmias, and cardiac arrest at the time of prosthetic insertion. This was observed most frequently in patients undergoing cemented arthroplasty.[172,173] Accordingly, thorough lavage and drying of the canal is recommended with gentle, if any, pressurization during cementation in more frail patients. In general, cement seems to provide better clinical results but should be used with caution.

Bipolar Versus Monopolar Hemiarthroplasty

Once a hemiarthroplasty has been chosen, further controversy surrounds the selection of either a unipolar (fixed head) or a bipolar bearing. The design rationale of the bipolar bearing, developed in 1974,[174] centers on an additional metal and polyethylene bearing surface that theoretically diminishes stress on the articular cartilage of the acetabulum and possibly decreases the rates of acetabular erosion noted in monopolar designs.[175-186] Multiple evaluations of whether any motion occurs at the bipolar bearing over time have been published.[187,188] Although earlier studies with older designs showed unpredictable motion at the inner bearing, a more recent study using contemporary implants demonstrated preservation of motion at the inner bearing in 93% of 177 hips evaluated fluoroscopically at a mean of 47 months postoperatively.[189] Additionally, the motion did not seem to deteriorate with time. Inner bearing motion may be successful in reducing the incidence of acetabular wear, as the developers of the prostheses theorized. However, none of these studies can accurately evaluate motion along the center of rotation of the femoral neck, such as is common with walking or sitting. In theory, even small amounts of motion could unload the acetabular cartilage and perhaps contribute to the longevity of the native acetabular articular surface. Although the controversy regarding preservation of motion will continue, what is most important is to know whether bipolar designs provide long-term pain-free ambulation with a low rate of acetabular protrusio or revision for acetabular wear. Several studies have compared bipolar and monopolar designs, and the literature is somewhat confusing. Beckenbaugh and associates[190] reported 92% survivorship in 51 patients with a cemented unipolar prosthesis, with a minimum age of 70 years and a 3-year follow-up. Cabanela and Van Demark[191] reported on 58 patients with 59 cemented Bateman bipolar prostheses and noted no revisions at a minimum follow-up of 2 years. Yamagata and associates[192] compared 682 fixed-head and 319 bipolar prostheses implanted for various diagnoses, using cemented and cementless techniques. The mean age of the patients was 73 years. They concluded that the revision rates were higher in the patients with fixed-head prostheses (12.5%) than for the patients with bipolar prostheses (7.2%). They also showed a significantly higher survivorship rate for cemented implants, regardless of head type. The Harris Hip Scores were better for the patients with bipolar prostheses. Marcus and associates[193] retrospectively compared 100 cementless Austin Moore-type prostheses to 80 cementless and cemented bipolar prostheses and found no difference in hip scores at 2 years. Lu-Yao and associates[3] examined the rates of revision comparing bipolar and unipolar designs with a minimum 7-year follow-up. The revision rate for the unipolar hemiarthroplasty was 20% and was 10% for the bipolar hemiarthroplasty. This is not surprising because patients who live longer are probably more active and will place more stress on the remaining articular surface.

Much of the literature on cementless unipolar prostheses presents alarming rates of failure. Kofoed and Kofod[164] followed 71 patients treated with a cementless unipolar device with a mean age of 82.5 years for 2 years. Overall, 37% of patients had poor results and required total hip arthroplasty. Of active patients, 55% required total hip arthroplasty. Acetabular degeneration was the most common reason for failure. These authors concluded that active patients, regardless of age, should not be treated with an Austin Moore-type implant. Other investigators also found problems with the Austin Moore-type implant with regard to revision rates and function. The data for cemented unipolar prostheses also have been reported. D'Arcy and Devas[194] studied a series of 354 cemented Thompson (fixed-head) hemiarthroplasties in patients with a mean age of 81 years. Of the 156 survivors available for review at 3 years, the failure rate was 18.9%. The most common reason for failure was acetabular erosion (11%).[194] Maxted and Denham[165] reported on 92 patients treated with cemented Thompson prostheses with a mean follow-up of 4 years. They reported an age-dependent 19% revision rate, with younger patients having more failures.[165]

When reviewing the literature comparing bipolar and unipolar hemiarthroplasties, patient age and the length of follow-up are important considerations because acetabular wear is a time-dependent phenomenon. It is unlikely that any differences will be noted among low-demand patients with short-term follow-up. However, if patients live longer and are more active, the differences will probably become clear. This remains one of the major challenges in prosthesis selection because the surgeon must attempt to estimate the patient's future activity level and life expectancy. Wathne and associates[195] compared 92 patients treated with a cemented bipolar prosthesis and 48 patients treated with a cemented modular unipolar prosthesis and found no difference in function at 1 year. Calder and associates[196] compared cemented unipolar to cemented bipolar prostheses in patients older than 80 years; at 2 years no difference was noted. Kenzora and associates[197] reported on 270 patients older than 65 years, comparing cementless unipolar to cementless bipolar and cemented bipolar prostheses; the best function was noted with a cemented bipolar prosthesis. Ong and associates[198] compared cemented bipolars and cemented unipolars with a mean follow-up of 4 years in 149 patients. There was no difference in functional outcome, mortality, or complications between the two groups. Haidukewych and associates[162] reported on 212 bipolar prostheses in patients with a mean age of 79 years at a mean follow-up of 6 years for the entire group; follow-up was 12 years for surviving patients. Only 10 hips underwent revision (4.7%). The most common reason for revision was femoral loosening, not acetabular wear. Most importantly, only one revision was performed for acetabular erosion. Therefore, the 10-year survivorship rate in this cohort free of revision for acetabular wear was 99.4%, and 96% of patients reported no pain or slight pain at follow-up. The dislocation rate was 1.9%.

In summary, there is justification in the literature for the use of both unipolar and bipolar bearings. In general, cemented fixation appears to provide better results and the choice of unipolar versus bipolar bearings should be based on surgeon preference, estimated patient activity, and life expectancy. It is the authors' preference to use cemented stems with unipolar bearings for minimally ambulatory patients, and patients who are community ambulators are treated with cemented stems that have bipolar bearings. Cementless Austin Moore-type prostheses are reserved for essentially nonambulatory patients who have dementia and prohibitive medical comorbidities.

The Role of Total Hip Arthroplasty

Historically, total hip arthroplasty has been reserved for patients with displaced femoral neck fractures and concomitant symptomatic degenerative changes of the hip. This combination of pathology is extremely rare, probably because patients with degenerative arthritis typically have stiff, thick hip capsules and will tend to fracture in the intertrochanteric region, not in the femoral neck. Recently, the indications for total hip arthroplasty have been broadened to include active elderly patients with acute femoral neck fractures. This has been based largely on the improved functional outcomes, documented in multiple studies comparing total hip arthroplasty to hemiarthroplasty.[93,97,199-202] Pain relief is, in all likelihood, more predictable with total hip arthroplasty. However, dislocation is the main concern when performing total hip arthroplasty for acute femoral neck fractures. Dislocation rates have averaged approximately 10% across multiple studies,[93,97,199-202] with approximately 25% of those dislocations becoming recurrent and chronic. A recent meta-analysis documented a 7% dislocation rate for total hip arthroplasty.[141] With the large number of hip fractures treated annually, the potential societal and economic impact of such complications is substantial. Several reasons have been postulated for this increased dislocation rate in this patient cohort. First, because these patients do not have the stiff hips so common in patients with osteoarthritis, they are likely to regain motion quickly and experience impingement and dislocatation. Additionally, these elderly patients may frequently have adduction and flexion contractures, poor muscle tone, poor balance leading to frequent falls, and difficulty complying with hip precautions. Despite the relatively high dislocation rate, most studies have demonstrated better function and pain relief with a total hip arthroplasty, and importantly, no increase in mortality or morbidity when comparing total hip arthroplasty to hemiarthroplasty or internal fixation. In one study considering the cost of revision and complications over a 2-year period, the most cost-effective method for treating patients with displaced femoral neck fracture was with cemented total hip arthroplasty.[6] Keating and associates[203] recently randomized 301 patients with a mean age of 60 years to undergo either open reduction and internal fixation, cemented bipolar hemiarthroplasty, or total hip arthroplasty. In this multicenter study involving 46 different surgeons, the internal fixation failure rate was 29%. The revision rate for patients treated with bipolar hemiarthroplasty was 5% and for total hip arthroplasty the rate was 8.5%. Three patients treated with total hip arthroplasty experienced dislocation. Total hip arthroplasty demonstrated the best functional outcome. Therefore, it can be concluded from the available literature that function appears to be generally superior with total hip arthroplasty, and there appears to be no increase in morbidity, mortality, or cost in performing a total hip arthroplasty compared with hemiarthroplasty or internal fixation. The main technical hurdle to overcome, therefore, is dislocation. With recent developments in cross-linked polyethylene and the trend to use larger diameter femoral heads in high-risk patients, dislocation rates may be potentially decreased. Additionally, selection of approaches that historically have demonstrated a lower dislocation rate, such as the anterolateral approach, may be prudent.[204] This may be especially advantageous to patients who have mild adduction and flexion contractures and spend most of their time in a seated position. Additional data are needed to determine whether these strategies will decrease dislocation rates.

In summary, total hip arthroplasty is a reasonable alternative for the treatment of displaced femoral neck fractures in the more active elderly cohort because of generally superior functional outcome. The surgeon and the patient should both be cognizant, however, that dislocation remains problematic and the selective use of larger diameter femoral heads, elevated lipped liners, and approaches that have been associated with a lower dislocation rate may be wise.

Prosthetic replacement remains an effective treatment option for the elderly patient with displaced femoral neck fracture. Revision rates have been shown to be consistently lower than those published for internal fixation, and in general, complication rates are low and functional results are good. The choice of prosthesis and fixation method should be individualized based on surgeon preference and patient characteristics such as bone quality, activity, medical comorbidity, and estimated life expectancy. Age alone should not be used to determine the ideal treatment method for the patient with a displaced femoral neck fracture. Additional research is needed to clearly document which prosthetic choice is superior.

International Comparisons of Hip Fracture Treatment

The Demographic Problem

Scandinavia and North America have already experienced a sizeable increase in the total number and incidence of hip fractures. The World Health Organization has estimated that 1.7 million hip fractures occurred worldwide in 1990, and the amount has been predicted to grow to over 6 million by year 2050. This increase is primarily the result of an increasing elderly population in Asia, Africa, and the Eastern Mediterranean region. The number of individuals in the world age 65 years or older now living will increase from 323 million to an estimated 1.55 billion by the year 2050.[205] This increase will have a dramatic influence on the number of patients with hip fractures that must be treated each year. Demographic changes alone will cause the annual number of hip fractures in the United States to more than double, from 238,000 in 1986 to 512,000 in the year 2040.

In Sweden, with a population of about 9 million, about 60,000 patients sustain an osteoporotic fracture each year; 18,000 of these fractures are of the hip. It is estimated that at the age of 50 years, every second Swedish woman has the risk of some type of osteoporotic fracture some time during her remaining lifetime. The risk for men is about half that for women. The risk has increased gradually over the decades, especially in individuals older than 80 years. Most of the more extensive fractures occur in the elderly, who often have coexisting diseases but still expect to live an independent, mobile, and pain-free life. A hip fracture can trigger a series of problems and treatments at different levels of care. The lifetime risk of sustaining a hip fracture for a woman in Sweden is estimated at 23% and for a man 11%.[206] This total increase in hip fractures is a potential threat to hospital resources and overall health economy. However, the prognosis for individual patients has improved over the decades because of improved treatment including optimized osteosynthesis and active rehabilitation. Many patients with hip fractures can rapidly return to their own homes, continue the rehabilitation there, and achieve the same level of function as before the fracture.[116,207-211] A few recent studies have reported a trend-break in hip fracture incidence,[212-215] particularly for women, whereas numbers continue to increase for trochanteric fractures in men.[215] However, large age cohorts of those vulnerable to fracture will override the lower incidence trend and will result in an overall increase of the number of hip fractures during the coming decades.

The incidence rates for hip fractures are higher in white populations than other populations and vary by geographic region. Age-adjusted incidence rates of hip fracture by gender are higher in Scandinavia than in North America, and lower in the countries of Southern Europe.[216,217] The absolute number of hip fractures in each region is determined not only by ethnic composition, but also by the size of the population and its age distribution. Consequently, about one third of all hip fractures in 1990 occurred in Asia, despite lower incidence rates among Asians. Almost half of the fractures occurred in Europe, North America, and Oceania, even though the population was smaller, because the population was older than average and composed largely of whites.[218] In Sweden, three of four patients with hip fractures are women.[103] This preponderance is explained because women outnumber men as age increases, and there is an increased incidence of osteoporosis during the postmenopausal period. Hip fractures are rare in patients younger than 50 years and constitute only 2% of the total.[219] The risk of hip fracture increases exponentially in patients age 50 years and older. The mean age of patients with a hip fracture in Sweden is now 81 years. Men have the same exponential increase as women in fracture risk with increasing age, but in men the fractures occur approximately 5 to 10 years later through the age range.

National Registration

In Sweden, a national registration of hip fracture treatment (RIKSHÖFT) was initiated in 1988.[220] This registration has attracted international interest and also resulted in the development of a comparable database within Europe, called Standardised Audit of Hip Fractures in Europe. The philosophy behind national registration is to improve the quality of care in all parts of the country and, through comparisons of everyday practice, to achieve a high treatment standard. In some years, the Swedish National Board of Health and Welfare and the Swedish Association of County Councils have provided financial support to these so-called "National Quality Registers." Through the registration, the orthopaedic departments also participate in a large prospective study; the magnitude of patients has scientific impact and supplements randomized studies with the broad application perspective of new and established methods.

In Sweden, the distribution of fracture types in approximately 80,000 registered patients was nondisplaced cervical fractures (Garden I and II) in 16.2%; displaced cervical fractures (Garden III and IV) in 37.0%; basicervical fractures in 3.5%; trochanteric two-fragment fractures in 22.6%; trochanteric multifragment fractures in 15.2%; and subtrochanteric fractures in 5.5%.

The two main groups are the cervical fractures and the trochanteric fractures. With increasing age, the proportion of trochanteric fractures increases. A geographical difference also exists. In Sweden and Norway, the ratio is close to 1:1, whereas Iceland and Finland have shown a higher proportion of cervical fractures.[221]

The costs of hip fractures are considerable.[218,222] In Sweden, the cost of treatment during the first year following hip fractures has been calculated to be around $420 million annually. Based on RIKSHÖFT data, the total annual cost including nursing care during the first 4 months after the hip fracture amounts to $140 million. In the United States, the

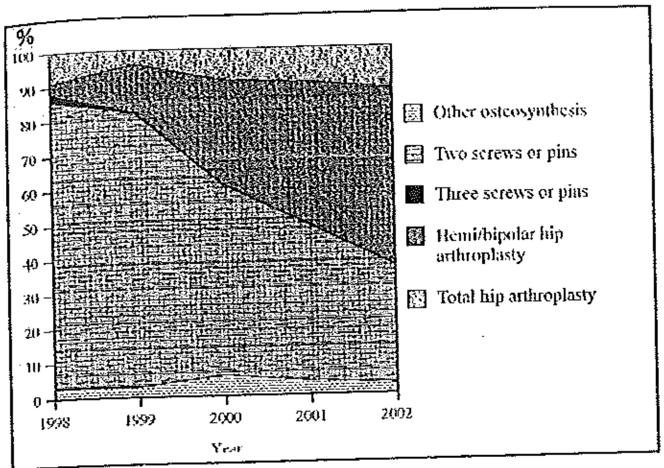

Figure 18 Trend in surgical procedures for displaced femoral neck fractures in Sweden from 1998 to 2002.

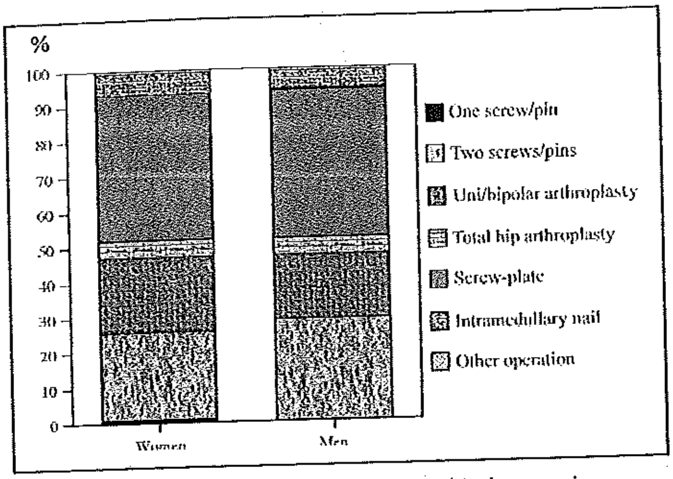

Figure 19 Surgical treatment methods used for hip fractures in women and men during 2002 in Sweden.

annual cost of treating hip fractures has been estimated to be nearly $10 billion. The high number of patients with hip fractures and the increasing costs of treatment make it necessary to optimize treatment. For femoral neck fractures, an optimized selected choice for the primary operation would decrease the need for revisions and diminish the overall treatment costs. This is the goal for future developments.

International Treatment Options

The best method to treat cervical (femoral neck) fractures has been disputed for decades. Different traditions prevail in different parts of the world. In Scandinavia, particularly in Sweden and Norway, virtually all cervical hip fractures have been treated with a primary osteosynthesis, whereas on the European continent, in Great Britain, and in the United States, most patients older than a certain age have been treated with arthroplasty, usually hemiarthroplasty.

In 2002, 27% of the patients in Sweden have been treated with osteosynthesis with two hook pins or two screws. Use of three or more screws or pins is rare (0.4%). Hemiarthroplasty was performed in 19% of the hip fractures, and total hip arthroplasty in 5%. These methods were mainly used for the femoral neck fractures. Telescoping screw-nail was used in 41%, and an intramedullary nail in 6%; these were primarily trochanteric fractures. Only 0.2% of the hip fracture patients did not have surgery. Since 1998, the trend in Sweden has been increased use of hemiarthroplasties for the displaced femoral neck fractures (Figure 18). For the displaced cervical neck fractures (Garden III and IV), hemiarthroplastics were performed in 3% in 1998 and in 51% of the patients in 2002. If total hip replacements are included, the arthroplasty use was 12% in 1998 and increased to 63% in 2002. This change is the result of several randomized studies. For trochanteric fractures, a screwplate has been the dominating treatment method. In 1998, 91% of the two-part trochanteric fractures were treated with a screwplate; this percentage has remained comparatively unchanged, with 94% performed in 2002. For the multifragment trochanteric fractures, 86% of the fractures were treated with a screwplate procedure in 1998, dropping slightly to 83% in 2002. In 2002, 15% of the multifragment fractures were treated with an intramedullary nail. There is little difference in the surgical treatment choice for women and men (Figure 19). However, men had somewhat more osteosynthesis with two pins or screws and somewhat fewer arthroplasties; the use of screw-plates was the same. There was likewise little difference in the fracture pattern between the sexes (Figure 20).

Based on close to 80,000 hip fractures surgically treated in Sweden from 1988 to 1997 before the trend toward increased use of arthoplasty, 21% of the total were operated with two screws, 24% with hook-pin osteosynthesis, 38% with telescoping screwplate, and fewer than 5% with some type of arthroplasty. The rest were treated with a variety of osteosynthesis methods. The screwplates are used for the trochanteric and sometimes the basicervical fractures as well as some of the subtrochanteric fractures.[223] Two hook-pins or two screws have been used for the cervical hip fractures, together with a minority of arthroplasties (Figure 21).

Improved techniques can now aid the surgeon in more accurate reduction of the fracture and placement of the internal fixation devices, thereby optimizing the stabilization of the fracture. The image intensifier is an indispensable tool. A biplanar apparatus is preferred because of better precision and shorter surgery times (Figure 22). The advantage of a biplanar

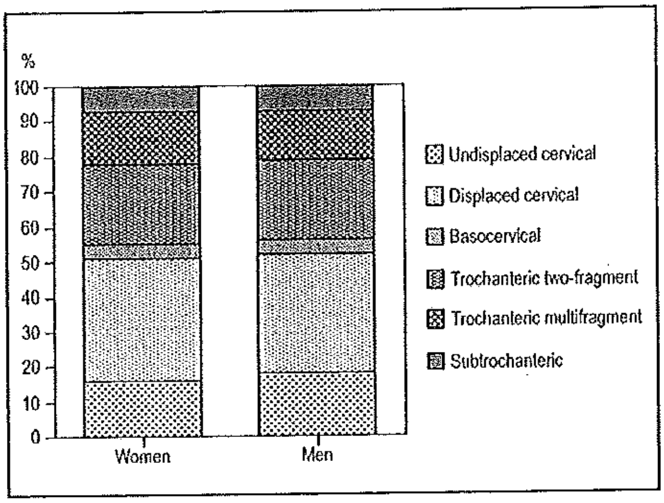

Figure 20 Hip fracture patterns in women and men in Sweden during 2002.

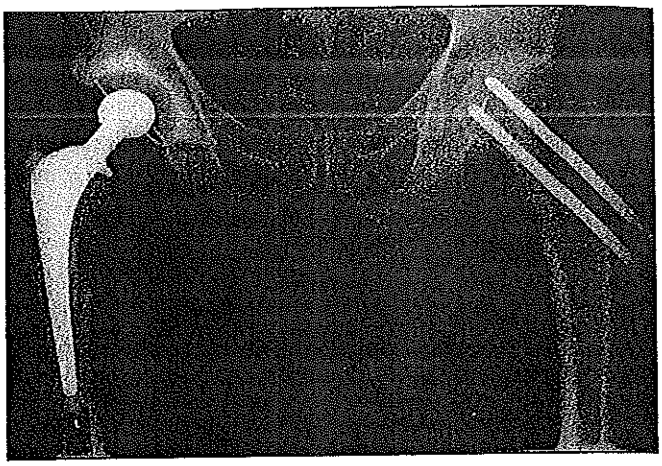

Figure 21 Radiograph of a patient demonstrating a healed femoral neck fracture on the patient's left side after hook-pin osteosynthesis and a cemented total hip arthroplasty without signs of loosening on the patient's right side.

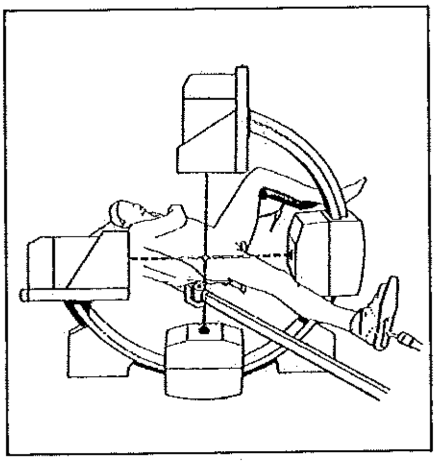

Figure 22 Positioning of the patient on the traction table with biplanar image intensifier. The horizontal x-ray tube (lateral view) is to the left of the surgeon. Images are shifted with a foot pedal.

image intensifier is that after positioning of the equipment, no further movements of the standard tube are necessary, which avoids jeopardizing the draping and thereby the sterility. Shifting between the views on the monitor is accomplished with a foot pedal, which saves considerable surgery time. Furthermore, the easy, rapid shifting between the positions increases the precision in the placement of the osteosynthesis material. The importance of a minimally invasive surgical technique to the circulation of the femoral head has been proved.[224] The channels should be predrilled, and the hammering in of osteosynthesis material is to be avoided. In addition, impaction of the fracture by hammering decreases the circulation to the femoral head. The best way to achieve compression in the fracture is by the patient's own muscle forces in weight bearing. For cervical fractures, parallel hook-pins or screws are usually used. To prevent these devices from sliding out during healing, they are either reinforced with hooks (hook-pins) or threaded in the end as screws. The most important factors for good healing have proved to be the fracture type, the positioning of the bony parts after reposition, and the positioning of the osteosynthesis material[225] (Figure 23). Criteria for acceptable reduction were no varus, maximum displacement of 2 mm, and valgus alignment of 0° to 15° on the AP view, and on the lateral view, a maximum displacement of 2 mm while allowing 20° of ventral and 10° of dorsal angular displacement. The hook-pin is a cannulated blunt pin (nail) with a diameter of 6.5 mm. It has a thin blade (hook) inside, which is driven out of the tip of the pin during the procedure. Criteria for the acceptable placement of the device were positioning of the distal pin close to the calcar on the AP view and centrally on the lateral view. The proximal pin should be close to the calcar on the lateral view and central on the AP view.

In Sweden, most orthopaedic departments use hook-pins.[117] In a consecutive prospective series of over 600 cervical fractures treated with hook-pin osteosynthesis and followed for 2 years clinically with radiographs, 23% of the original patients showed healing complications.[117] After 2 years, 31% of the patients without hip problems had died from other diseases. Among the surviving patients, the total healing complications amounted to 32%. The need for revision with a secondary total hip arthroplasty for healing disturbance was 13% for the total number of patients and 19% among the survivors. Similar results have been achieved with optimized screw osteosynthesis by dedicated surgeons. A randomized study in Norway between different osteosynthesis methods has demonstrated the importance of repositioning and place-

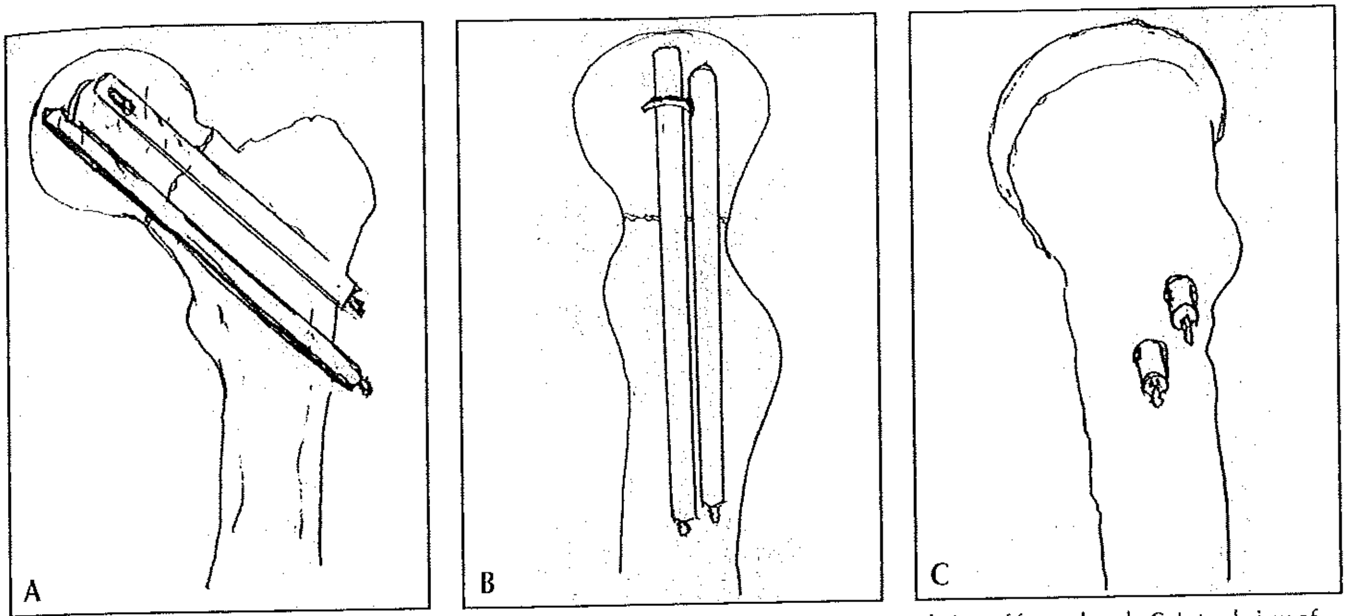

Figure 23 Schematic representation of positioning of hook-pin osteosynthesis. **A,** AP view. **B,** Lateral view of femoral neck. **C,** Lateral view of femoral shaft and pin entrance.

ment of the osteosynthesis material.[225] Osteosynthesis as the sole method for surgical treatment of all cervical hip fractures was successful in 78% of patients. Screws showed higher risk of drill penetration of the femoral head and more femoral head necrosis than the hook-pin method. Thus, osteosynthesis can provide on average 80% of the patients a definitive good treatment of the hip fracture. After 2 years, these patients either have a healed fracture without change of the femoral head (50% of patients) or the patients have died from other diseases in the meantime without healing problems from the hip (30% of patients). If both the reduction of the fracture and the placement of the osteosynthesis material were rated as good according to the criteria given above and no drill penetration had occurred, a successful 2-year outcome was achieved in 86% of the screw group and in 89% of the hook-pin group.

The previous tradition in some areas to treat all cervical fractures regardless of type by a primary arthroplasty has been modified during recent years, and there is now a general agreement that nondisplaced fractures should be treated with osteosynthesis.[226-228] Many centers now also advocate osteosynthesis for younger patients with displaced fractures, and the age limit for arthroplasty has been shifted more toward the elderly. It is the physiologic age that is important. The recommendation given by Parker and Pryor in Great Britain[226] is an age limit of 70 years. Kyle[227] from the United States advocates a physiologic age of 75 years or older for prosthetic replacement, whereas closed reduction and internal fixation is recommended for younger patients. The recommendations for the type of prosthetic replacement differ. Some advocate the same type for all patients, whereas Kyle[227] recommends an Austin Moore-type prosthesis for minimal ambulators, a bipolar prosthesis for nursing home ambulators or low-level community ambulators, and a total hip replacement for patients with concomitant osteoarthrosis of the fractured hip, rheumatoid arthritis, tumor, or failed pinning.

The rationale for primary arthroplasty is that no healing complication can appear if the fracture has been taken away and the femoral head is substituted with a metal one. This reasoning, however, overlooks the fact that many of these fractures would have healed if treated with primary osteosynthesis. In this instance, the desire to overcome future healing complications leads to increased time in surgery, greater blood loss, and a greater wound compared with the use of percutaneous pinning. Other potential complications are also introduced, such as displacement of the arthroplasty and, in the long run, loosening. After replacement of only the femoral head with a hemiarthroplasty, the articular cartilage in the acetabulum will wear away over time. Conversely, it has been postulated that elderly patients have less risk of reaching this stage because of other concomitant diseases and expected average mortality. However, with a primary arthroplasty, the trauma from surgery is greater and the mortality reported in the literature is higher.[5,141,219,229-233] There is a great need for randomized studies that compare osteosynthesis and arthroplasty for primary treatment of cervical fractures. Importantly, there is a need for studies comparing treatment methods now used on a large scale in different parts of the world as the primary method. This point was also recently emphasized in a meta-analysis of randomized studies that compared internal fixation and arthroplasty for displaced fractures of the femoral neck.[141]

Since 1998 in Sweden, attempts to find the patients best suited for arthroplasty have intensified. Randomized studies have been initiated, and on the basis of new results, the treatment policy has changed. On average, half of the patients with displaced fractures are treated primarily with an arthroplasty, whereas the other half are still treated with a primary osteosynthesis.[142,156,234,235] For the nondisplaced fractures, it is undisputed internationally that all should be treated with a primary osteosynthesis. The current indication for a primary arthroplasty is a clearly displaced cervical fracture if the patient is walking before the injury and has a biologic age of 70 to 75 years or older, according to the Swedish National Guidelines for the treatment of hip fracture patients.[236] Thus, patients with moderately displaced cervical fractures and biologically younger patients undergo primary osteosynthesis. Also, patients who could not walk before their fracture are determined to not need major arthroplasty, and patients with dementia who have undergone arthroplasty have an increased risk of dislocation. Although the optimum proportions of osteosynthesis and arthroplasty are being sought, the Scandinavian experience clarifies that there is no reason to "behead all because some fail."

Summary

Femoral neck fractures constitute an epidemic, and successful management of these injuries is important to society as well as to the individual patient. All patients with hip fractures should be treated with thromboembolic prophylaxis, prophylactic antibiotics, and nutritional support. The options for management of the displaced femoral neck fracture are well defined; the challenge lies in defining the ideal patient for each intervention. There is a general consensus that repair of the fracture with anatomic reduction and multiple screw fixation, performed as expeditiously as possible, is the treatment of choice in younger, healthy, and active individuals. Internal fixation should be performed with careful attention to detail. Nonanatomic reduction increases the risk of failure; open reduction should be considered for all patients to decompress intracapsular hematoma as well as maximize the opportunity to achieve perfect fracture reduction. Augmentation of bone density with calcium phosphate ceramics or other materials may decrease the risk of fixation failure in the future.

There is a decreasing use of bipolar hemiarthroplasty and increasing use of both unipolar hemiarthroplasty and total joint arthroplasty. Mounting evidence exists that total joint arthroplasty provides the best and most durable function for very active patients; it is also cost-effective when the cost of treating complications after internal fixation is considered. Total joint arthroplasty also is associated with an increased rate of revision surgery. Recent advances in hip arthroplasty, such as the increased use of large-diameter heads and the availability of constrained acetabular liners, may further expand the indications for total joint arthroplasty.

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