43 Vascularized Pedicle Iliac Bone Grafting for Osteonecrosis of the Femoral Head

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43.1 Introduction

Osteonecrosis of the femoral head (ONFH) is a debilitating disease and eventually leads to collapse if left untreated. This condition is estimated to account for more than 10 % of the total hip arthroplasties (THAs) performed each year in the United States and more than 50 % in many Asian countries [1–4]. ONFH often affects young active patients and the incidence of bilateral hip involvement is around 50–80 % [3, 4]. Even though the success rate and the intermediate term of prosthesis survival by using newer bearing surface are improving as compared to the conventional THA, preservation of the femoral head is still the goal in those young active patients.

Since ONFH is frequently found in patients between the ages of 20 and 50 years, many techniques to salvage the ONFH in young patients have been reported. Among them, the use of vascularized iliac bone grafting based on a pedicle of the circumflex iliac artery has become popular because it is in vicinity to the lesion and needs no microsurgical anastomosis. It has also been successfully used for nonunion of the femoral neck fracture or large defects of the proximal femur.

In addition to the vascularized iliac pedicle bone grafts, there are other alternative grafts around the hip that can be used to repair the necrotic femoral head. The quadratus femoris muscle pedicle graft is supplied by the muscular branch of the lateral femoral circumflex artery and is commonly used for the repair of femoral neck fracture nonunion (Meyer procedure). It has been successful in femoral neck fracture nonunion, but it is seldom used in the ONFH repair. The reason is because the graft is a posterior-based muscle pedicle graft, whereas the osteonecrotic lesion is usually located in the anterosuperior quadrant of the femoral head. Furthermore, there is limitation in the graft size that the mechanical strength of the proximal femur will be compromised if the donor site is too big. The gluteus minimus pedicle graft has also been used in the repair of ONFH [5]. It is a relatively simple procedure because the surgical approach is identical to the direct lateral approach to the hip. The graft is supplied by the muscular branch of the superior gluteal artery. Care should be taken in the dissection of the gluteal muscles to avoid inadvertent injury to the vessel. By gently elevating the insertion of the gluteus medius muscle, the vascular pedicle can be found in the fat pad between the gluteus medius and minimus about 2–3 cm from the greater trochanter tip. By using oscillating saw, the entire insertion of the gluteus minimus on the greater trochanter can be harvested as a cortico-cancellous graft. The potential drawbacks of the graft are (1) the osteonecrosis is sometimes extended to the trochanteric area that the graft itself is also necrotic; (2) the harvest of the graft may weaken the femoral neck that additional fixation may be needed; and (3) part of the hip abductor muscles are sacrificed that is less favorable for the hip function.

Vascularized iliac bone graft (VIBG) has been used for the repair of femoral neck fracture nonunion or proximal femoral deficiency [6, 7]. As compared with the free vascularized fibular grafting, the VIBG has been less reported in the literature. We and others have used VIBG for the salvage of the ONFH. This chapter will review the anatomy, the surgical technique, the indication, the clinical results, and other combined technique of the VIBG.

43.2 Anatomy

The blood supply to the iliac crest is majorly contributed by the deep circumflex iliac artery (DCIA) which is arisen from the lateral or posterolateral aspect of the external iliac artery just above the inguinal ligament and opposite to the inferior epigastric artery (Fig. 43.1). Other arteries such as

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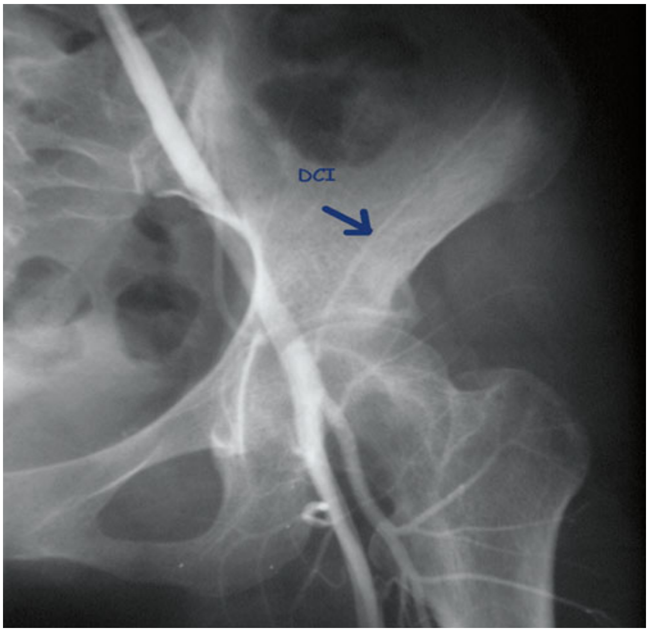

Fig. 43.1 Superselective angiography. The deep circumflex iliac (*DCI*) artery is shown

the superior gluteal, lateral circumflex femoral, and superficial circumflex iliac artery also contribute, but the tributaries are smaller in diameter. The DCIA runs upward and laterally between the transversalis fascia and the extraperitoneal fat. It gives out a number of branches in the course and pierces through the abdominal muscle layers to the inner surface of the iliac crest in the insertion of iliacus and transversus muscles [8].

The external diameter of the DCIA is usually around 2–2.5 mm and can be easily handled without microscopic magnification. The artery runs along the inner lip of the iliac crest and diverts away from the upmost point of the iliac crest to give off multiple intramuscular branches to the iliacus and anastomoses with the iliolumbar and superior gluteal artery. From the origin of the external iliac artery to the iliac crest, the vascular pedicle can be 8–10 cm in length which provides a versatile radius to swing around the proximal femur. All along its course, the DCIA is accompanied by its venae commitantes that drain into the external iliac vein or femoral vein.

Most of the surgeries use the DCIA as the vascular pedicle because the constant position and diameter of the vessels make it very suitable for harvest and transplantation. In addition to the DCIA, some surgeons used the superficial circumflex iliac artery that travels between the fatty tissue and fascia in the inguinal region [9, 10]. It is noted that the vessels of the superficial circumflex iliac artery are smaller in size and more difficult to harvest.

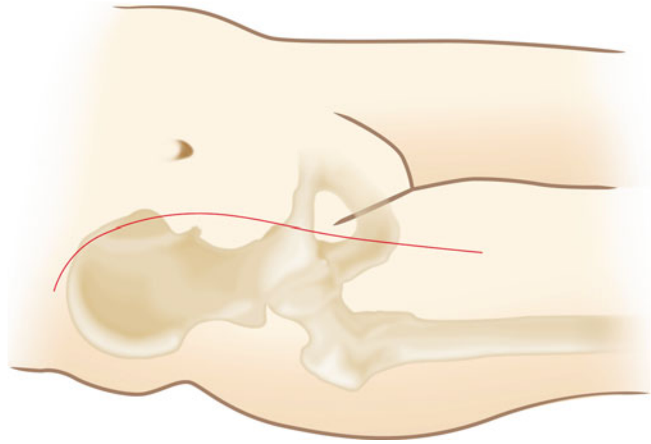

Fig. 43.2 Skin incision for VIBG surgery

43.3 Surgical Technique

Under general anesthesia, patient is put in the supine position with a sandbag behind the operated side of the pelvis. A long and curve skin incision is made on the iliac crest 8 cm pass the anterior superior iliac spine (ASIS), along the inguinal ligament, with the distal limb extended medially to the hip joint (Fig. 43.2). The femoral artery and the vein are looped to identify the external iliac artery. By gentle traction on the external iliac artery, tributaries of the external iliac artery can be exposed. The superficial circumflex iliac vessels and the deep circumflex iliac vessels are usually arising from the external iliac vessels just opposite to the origin of the inferior epigastric artery and could be easily traced to the inner lip of the iliac crest, into which feeding branches were sent (Fig. 43.3a). The external and internal oblique abdominal muscles are cut from its insertion on iliac crest. Dissection of the vascular pedicle should be carefully performed after opening the inguinal ligament and the transversalis fascia. The first few tributaries behind the inguinal ligament can be ligated. Beyond the point of ASIA, a sleeve of iliacus muscles should be left on the inner lip of the iliac bone that encases the vascular pedicle to avoid overzealous dissection and inadvertent tear of the feeding vessels. A suitable-size bone graft is harvested with its attached vascular bundle and muscle sleeve (Fig. 43.3b).

The hip joint is exposed by using the inferior limb of the skin incision. Between the sartorius muscle and the tensor fascia latae (Smith-Petersen's interval), the anterior hip joint capsule is exposed by retracting the rectus femoris medially and the hip abductors laterally. The anterior joint capsule is incised in an H-shape manner to expose the head-neck junction of the hip joint. Rotation and manipulation of the hip

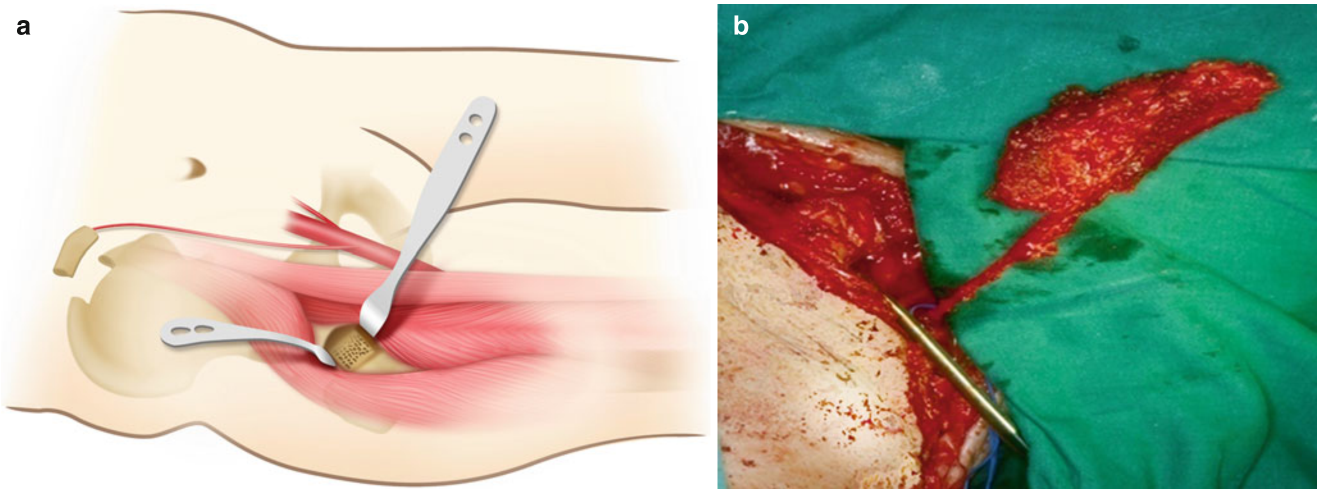

Fig. 43.3 Deep dissection. (**a**) The DCIA can be found opposite to the inferior epigastric artery. Two Hohmann retractors are put intra-articularly for exposure. A bone trough is made on the femoral neck. (**b**) VIBG with vascular pedicle

will bring the femoral head into view. A bone trough about 1.5 cm × 3 cm is made in the femoral neck leading into the head using sharp narrow osteotomies (Fig. 43.3a). Repeated sharp cuts along the top end of the trough open into the ischemia area of the femoral head. The hard and sclerotic avascular bone is removed using high-speed burrs as thoroughly as possible. If the cartilage is cracked that can been seen directly from the inside, careful out-pushing of the cartilage shell from inside the femoral head can correct the indentation and make it more congruent with the acetabulum.

The void and cavity after debridement is filled with bone chips by gentle impaction of a layer of cancellous bone to the subchondral level. The remaining space is to be filled in with a tailored piece of iliac crest bone with its intact blood supply of DCIA. A tunnel below the iliopsoas is made by blunt dissection with the hip in flexion. A large-size Penrose drain is passed beneath the inguinal ligament along the tunnel as a channel to transfer the graft to the anterior aspect of the femoral neck. The entire graft is slid into the Penrose drain and wrapped by it. By carefully pushing of the graft from the inside of the iliopsoas, the graft can be transferred to the anterior hip with intact pedicle. The Penrose drain is then incised completely with scissor to bring out the graft. As long as the graft is transferred to the anterior hip joint, it can be trimmed to a suitable size to be inserted through the bone trough into the femoral head. The graft can be pushed into the trough to produce a locked-in position and additional holding implant is unnecessary.

Postoperatively, the surgically treated hip is put in a position with 30° flexion and neutral rotation. This posture is advised for approximately 1 week to relax the tension of the vascular pedicle. Hip motion is encouraged as tolerated. The patients are instructed to use double crutches to avoid full weight bearing on the involved limb for 6 weeks. During the following weeks, the amount of weight bearing can be gradually increased by using a single crutch and progresses to a fully unassisted weight bearing by 6 months.

43.4 Indication

The indications for VIBG have not been well established in the literature. The factors affecting treatment results include staging (demonstration of the lesion by radiograph or magnetic resonance imaging, size of the necrotic segment, location of lesion relative to the weight-bearing area, the amount of femoral head depression, and the acetabular involvement), risk factors (use of steroid, medical comorbidities, or systemic disease), and patient-specific factors (age, activity level, or body mass).

In a survey of treatment modalities in the North America, total hip replacement is the most commonly selected treatment of postcollapse ONFH, and core decompression is the most frequently offered treatment for symptomatic precollapse ONFH [11]. Vascularized bone grafting is suggested by only 3–10 % of the responders who are active members of the professional society. It is generally agreed that a symptomatic case with the lesion size more than 30 % of the femoral head needs operative treatment to prevent early collapse of the femoral head. For asymptomatic necrotic lesions with an area smaller than 30 % of the femoral head, close follow-up without treatment appears to be adequate in most of the cases [3, 4, 12].

Table 43.1 Summary of success rate

Authors	Case no.	Success rate		Follow-up (years)
		Precollapse	Postcollapse	
Iwata et al. [9]	23	17/20	0/3	1–6
Leung [19]	21	4/5	4/16	5–12
Wassenaar et al. [20]	12	3/5	2/7	4.1
Ishizaka [21]	31	9/18	7/13	2–11
Hasegawa et al. [10]	31	12/27	2/4	8
Feng et al. [22]	17	7/12	3/5	5.7
Kern et al. [23]	80	Clinical 50 %; radiographic 47.5 %		5.6
Pavlovcic et al. [14]	24	7/7	3/17	12
Yen et al. [17]	39	16/23	6/16	2–6
Eisenschenk et al. [18]	102	Clinical 87 %; radiographic 56.1 %		5
Nagoya et al. [15]	35	12/28	0/7	8.5
Babhulkar [16]	31	9/9	21/22	5–8
Chen et al. [13]	33		8/33	7.1

In the literature, most of the studies of VIBG reported a mix group of hips ranging from precollapse stage to early postcollapse stage. In a study of 33 segmental collapse hips, 26 ARCO stage IIIA and 7 ARCO stage IIIB, only 24 % of the hips treated with VIBG survived without converting to total hip replacement with a mean survival of 74 months. The authors concluded that VIBG is not indicated for the treatment of ONFH with segmental collapse [13]. Other studies also reported similar results in postcollapse hips with a relatively low successful rates [9, 10, 14, 15]. As a contrast, Babhulkar reported a clinical success rate of 95 % in 22 ARCO III hips with a follow-up period of 5–8 years by using vascularized iliac pedicle grafting [16]. However, by looking at the illustrated cases in that report, many of the clinically successful cases showed radiographic collapse of the femoral head. Based on the findings, the rational indication for VIBG should be ONFH without collapse in a young active patient with the lesion more than 30 % of the femoral head. Contraindications include a segmental collapse hip, preexisting thromboembolic disease, a risk of bleeding or thrombocytopenia, a questionable vascular supply to the iliac graft due to factors such as surgery or trauma, multifocal osteonecrosis involving the ilium, untreated inguinal or femoral hernia, and asymptomatic hips [13].

43.5 Clinical Results

Between 1994 and 1999, the author had performed 100 cases of VIBG in 86 patients at the author's institute. Thirty-nine hips in 33 patients with a minimal follow-up of 2 years were reported [17]. The overall clinical success rate was 82 % and the radiographic success rate was 56 %. The rate of conversion to replacement arthroplasty was 10.3 %. We had further followed up 33 hips with preoperative segmental collapse lesions for 7.1 years. VIBG by using the technique described in this chapter had delayed the conversion to total hip arthroplasty by an average of 7 years in ARCO stage IIIA hips and by 2.9 years in ARCO stage IIIB hips [13].

Eisenschenk et al. had performed VIBG in 102 hips and achieved 87 % clinical success rate and 56.1 % radiographic success rate [18]. Many other reports have been published by using similar technique as described in this chapter [14–23]. The clinical success rate in precollapse hips ranged from 43 to 100 % with an average success rate around 72 % (Table 43.1). Iwata and Hasegawa had used superficial circumflex iliac vessels as the pedicle in their patients and had achieved a 52–74 % success rate [9, 10].

In postcollapse hips, the success rate differed between reports with 0 % in some reports and 95 % in one report [16]. The majority of the reports had a success rate less than 50 %. In view of these, some surgeons had developed combined surgical procedures to improve the clinical results and to salvage the segmental collapsed hips.

43.6 Combined Technique

Transtrochanteric osteotomy has been successful in hips where the intact articular surface is larger than 36 % of the femoral head and the extent of necrosis is limited [24]. For extensive or widely collapsed lesions, it is challenging to salvage the hip by one surgical procedure. Combined technique of proximal femur osteotomy and vascularized iliac bone grafting are intended to move the necrosis away from weight-bearing zone and provide mechanical support with viable bone at the same time. It is an appealing procedure in extensive and widely collapsed lesion in young patients. However, the combined surgical technique and procedure is more complex than either technique alone.

Two types of transtrochanteric osteotomy combined with vascularized iliac grafting were reported in the literature. One is the combination of transtrochanteric rotational osteotomy and vascularized iliac grafting. In 12 hips with extensive and widely collapsed necrotic lesion, the combined procedure was effective to prevent endoprosthesis replacement in 11 hips with a mean follow-up of 81 months [25]. In 17 hips with the necrosis more than two-thirds of the weight-bearing zone of the femoral head, the combined rotational osteotomy and vascularized iliac grafting prevented disease progression in 12 hips with a mean follow-up of 51 months [26]. When combining the rotational osteotomy with the vascularized iliac grafting, care must be taken to plan the direction of rotation and the position of the vascularized graft [27, 28]. A trough in the femoral neck to the necrotic femoral head needs to be designed properly for debridement and grafting in accordance to the degrees of rotation. The vascularized graft should be put immediately below the weight-bearing zone after rotation. Temporary fixation of the rotational osteotomy can facilitate the procedure. Definite fixation of the rotated femoral head can be done after trimming and transferring the graft through the bone tunnel.

The other type of transtrochanteric osteotomy combined with vascularized iliac grafting is a valgus/varus and/or flexion/extension osteotomy. It is simpler than the rotational osteotomy. In a series of 44 hips followed for 13.5 years, 34 % were converted to total hip arthroplasty while 90 % had progressive arthritis demonstrated by radiographs [29]. The authors suggested that this combination technique should be considered only in young symptomatic patients with good preoperative clinical function and Ficat stage II disease.

43.7 Graft Viability and Assessment Tools

The graft viability can be assessed postoperatively by several methods. Eisenschenk et al. had followed 82 patients for 5 years. In 42 patients, a superselective angiography was performed. Those angiographies showed perfusion of the grafts in 35 hips (83.3 %) [18]. The overall clinical success was achieved in 86.6 % of the patients. Although an angiography is a reliable tool to demonstrate the vascular pedicle after transplant, it is difficult to assess the viability of the necrotic femoral head and the revascularization of the necrotic lesion. In addition, an angiography is more invasive than other studies. Duchow et al. had used Doppler ultrasound to detect the blood flow of the VIBG [30]. However, it needs more experienced hands and is more technical demanding.

Nuclear medicine bone scintigraphy can also be used to evaluate the graft viability [31]. We had used single-photon emission computed tomography (SPECT) in 9 hips treated by VIBG [13]. The graft viability could be confirmed in 8 hips (89 %). However, a SPECT can only demonstrate the perfusion of the graft and the femoral head. Detailed information such as the extent of revascularization and the graft incorporation is difficult to assess by SPECT. Other nuclear medicine scan, such as positron emission tomography, theoretically can be used to evaluate the graft viability, healing, revascularization, and hemodynamic changes in the femoral head [32]. It has, however, not been reported in the literature.

In the literature, the most feasible noninvasive method to assess the graft viability and reparative process in the femoral head is a MRI study [13, 20, 33]. It is useful in most cases that the VIBG could be pushed into the bone trough without additional metal screw fixation. The signal intensity characteristics of the grafts can be compared with the normal fat marrow signals. An iso- or hyperintense signal in the graft is considered viable. Contrast enhancement by Gadolinium can be used to further evaluate the enhancement of the graft and the surrounding environment. The graft viability had been demonstrated by MRI in 82–100 % of hips treated by vascularized iliac grafting [10, 13, 18].

43.8 Summary

To preserve the femoral head and not to replace with prosthesis remains to be a challenge for the treatment of ONFH. VIBG with the feeding vessel of DCIA is a reliable graft with high rates of graft viability. The graft is corticocancellous and contains red marrow to provide osteogenic and revascularization potentials. No microsurgical anastomoses are required in the operation. The clinical results in precollapse ONFH are promising and can prevent or delay the total hip arthroplasties in most of the cases. Its use in segmental collapse ONFH remains controversial. To simultaneously transpose the intact articular surface and transfer a vascularized graft to weight-bearing zone of the necrotic femoral head has been tried. However, the combined procedure is difficult and complex to perform. Since the prognosis and long-term survival of ONFH rely on early diagnosis and intervention, the mainstay of treatment goals should emphasize on screening of patients with high risks, educate medical professions about the disease, and use of highly sensitive and accurate diagnostic tools such as MRI or PET scan to make early diagnosis.

References

1. Lee MS, Hsieh PH, Shih CH, Wang CJ. Non-traumatic osteonecrosis of the femoral head – from clinical to bench. Chang Gung Med J. 2010;33:351–60.
2. Lee MS, Chang YH, Chao EK, Shih CH. Conditions before collapse of the contralateral hip in osteonecrosis of the femoral head. Chang Gung Med J. 2002;25:228–37.
3. Lieberman JR, Berry DJ, Mont MA, Aaron RK, Callaghan JJ, Rayadhyaksha A, Urbaniak JR. Osteonecrosis of the hip: management in the twenty-first century. J Bone Joint Surg. 2002;84A: 834–53.

4. Mont MA, Jones LC, Hungerford DS. Nontraumatic osteonecrosis of the femoral head: ten years later. J Bone Joint Surg. 2006;88A: 1117–32.
5. Forgon M, Montskó P. Muscle-pedicle grafts or muscle-pedicle-bone grafts in the treatment of avascular necrotic femoral heads. Arch Orthop Trauma Surg. 1996;115:223–6.
6. Hou SM, Hang YS, Liu TK. Ununited femoral neck fractures by open reduction and vascularized iliac bone graft. Clin Orthop. 1993;294:176–80.
7. Lee SS, Ueng SWN, Shih CH. Aneurysm-induced intertrochanteric bone loss reconstructed by a vascularized iliac graft. A case report. J Trauma. 1999;46:944–7.
8. Swenson TM, Urbaniak JR, Sotereanos DG. A surgical guide for identifying the lateral femoral circumflex vessels during free vascularized fibular transfer for avascular necrosis of the femoral head. J Reconstr Microsurg. 1996;12:1–4.
9. Iwata H, Torii S, Hasegawa Y, Itoh H, Mizuno M, Genda E, Kataoka Y. Indications and results of vascularized pedicle iliac bone graft in avascular necrosis of the femoral head. Clin Orthop. 1993;295:281–8.
10. Hasegawa Y, Iwata H, Torii S, Iwase T, Kawamoto K, Iwasada S. Vascularized pedicle bone-grafting for nontraumatic avascular necrosis of the femoral head. A 5- to 11-year follow-up. Arch Orthop Trauma Surg. 1997;116:251–8.
11. McGrory BJ, York SC, Iorio R, Macaulay W, Pelker RR, Parsley BS, Teeny SM. Current practices of AAHKS members in the treatment of adult osteonecrosis of the femoral head. J Bone Joint Surg. 2007;89A:1194–204.
12. Nam KW, Kim YL, Yoo JJ, Koo KH, Yoon KS, Kim HJ. Fate of untreated asymptomatic osteonecrosis of the femoral head. J Bone Joint Surg. 2008;90A:477–84.
13. Chen CC, Lin CL, Chen WC, Shih HN, Ueng SWN, Lee MS. Vascularized iliac bone-grafting for osteonecrosis with segmental collapse of the femoral head. J Bone Joint Surg. 2009;91A:2390–4.
14. Pavlovcic V, Dolinar D, Arnez Z. Femoral head necrosis treated with vascularized iliac crest graft. Int Orthop. 1999;23:150–3.
15. Nagoya S, Nagao M, Takada J, Kuwabara H, Wada T, Kukita Y, Yamashita T. Predictive factors for vascularized iliac bone graft for nontraumatic osteonecrosis of the femoral head. J Orthop Sci. 2004;9:566–70.
16. Babhulkar S. Osteonecrosis of femoral head: treatment by core decompression and vascular pedicle grafting. Indian J Orthop. 2009;43:27–35.
17. Yen CY, Lee SS, Yuan LJ, Fu TS, Chan YS, Chen CY, Tu YK, Ueng SWN. Vascularized island pedicle iliac bone grafting for avascular necrosis of the femoral head. Chang Gung Med J. 2000;23:536–41.
18. Eisenschenk A, Lautenbach M, Schwetlick G, Weber U. Treatment of femoral head necrosis with vascularized iliac crest transplants. Clin Orthop. 2001;386:100–5.
19. Leung PC. Femoral head reconstruction and revascularization. Treatment for ischemic necrosis. Clin Orthop. 1996;323:139–45.
20. Wassenaar RP, Verburg H, Taconis WK, van der Eijken JW. Avascular osteonecrosis of the femoral head treated with a vascularized iliac bone graft: preliminary results and follow-up with radiography and MR imaging. Radiographics. 1996;16:585–94.
21. Ishizaka M, Sofue M, Dohmae Y, Endo N, Takahashi HE. Vascularized iliac bone graft for avascular necrosis of the femoral head. Clin Orthop. 1997;337:140–8.
22. Feng CK, Yu JK, Chang MC, Chen TH, Lo WH. Vascularized iliac bone graft for treating avascular necrosis of the femoral head. Zhonghua Yi Xue Za Zhi. 1998;61:463–9.
23. Kern O, Klöckner C, Weber U. Femur head preserving therapy, using vascular pedicled iliac bone graft, in segmental femoral head necrosis. Orthopade. 1998;27:482–90.
24. Sugioka Y, Hotokebuchi T, Tsutsui H. Transtrochanteric anterior rotational osteotomy for idiopathic and steroid-induced necrosis of the femoral head. Indications and long-term results. Clin Orthop. 1992;277:111–20.
25. Nakamura Y, Kumazawa Y, Mitsui H, Toh S, Katano H. Combined rotational osteotomy and vascularized iliac bone graft for advanced osteonecrosis of the femoral head. J Reconstr Microsurg. 2005;21:101–5.
26. Matsusaki H, Noguchi M, Kawakami T, Tani T. Use of vascularized pedicle iliac bone graft combined with transtrochanteric rotational osteotomy in the treatment of avascular necrosis of the femoral head. Arch Orthop Trauma Surg. 2005;125:95–101.
27. Noguchi M, Kawakami T, Yamamoto H. Use of vascularized pedicle iliac bone graft in the treatment of avascular necrosis of the femoral head. Arch Orthop Trauma Surg. 2001;121:437–42.
28. Kubo T, Kobayashi M, Ishida T, Yamazoe S, Fujioka M, Inoue S, Hirasawa Y. Non-traumatic osteonecrosis of the femoral head treated with transtrochanteric anterior rotational osteotomy combined with vascularized iliac bone grafting. J Orthop Sci. 2000;5:610–3.
29. Fuchs B, Knothe U, Hertel R, Ganz R. Femoral osteotomy and iliac graft vascularization for femoral head osteonecrosis. Clin Orthop. 2003;412:84–93.
30. Duchow J, Kubale R, Hopf T. Color Doppler imaging assessment of blood flow in vascularized pedicle grafts for avascular necrosis of the femoral head: angiographic correlation. J Ultrasound Med. 1998;17:509–12.
31. Cheung HS, Stewart IE, Ho KC, Leung PC, Metreweli C. Vascularized iliac crest grafts: evaluation of viability status with marrow scintigraphy. Radiology. 1993;186:241–5.
32. Huang MJ, Hsieh PH, Ueng SWN, Ho KC, Yen TZ, Lee MS. Use of positron emission tomography to detect infection around antibiotic-loaded cement spacers in patients with high C-reactive protein levels. Orthopedics. 2011;34:605–9.
33. Tan CF, Ng KK, Yem PS, Ng SH, Cheung YC, Wan YL. Viability of vascularized bone grafts; perfusion studies by dynamic enhanced MRI and bone scan. Transplant Proc. 2001;33:623–4.