Harvesting Iliac Crest Bone Graft: A Narrative Review and Cost Analysis

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Objectives: This review summarizes harvest techniques, graft volume, postoperative pain, functional limitations, complications, and costs associated with the iliac crest bone graft (ICBG).

Design: Literature review and summary.

Main Outcome Measurements: harvest techniques, graft volume, postoperative pain, functional limitations, complications, and costs

Results: On average, anterior ICBG harvest took 33 minutes, and posterior ICBG took 40 minutes. Anterior ICBG was faster to perform, and therefore cheaper, compared to posterior ICBG ($3,037 vs $3,660). Notably, operating room time cost varies considerably.

Conclusions: The iliac crest is readily accessible in both supine and prone positions. ICBG can be harvested as corticocancellous or cancellous bone graft, depending on the structural integrity desired. The most common complications associated with ICBG harvest are donor site pain and cosmetic deformity due to the iliac crest defect. Major complications, though rare, include deep infection, fracture, and neurovascular injury. Surgeons must be familiar with relevant anatomy, harvest techniques, bone graft volume, and potential complications associated with iliac crest bone graft to decrease morbidity

Level of Evidence: Level 4; Retrospective cost-analysis

Key Words: iliac crest, bone graft, bone defect, autograft, cost

INTRODUCTION

Although utilization of allograft, synthetic materials, and demineralized bone matrix (DBM) has increased, autologous bone graft is still considered "gold standard" as it contains all properties necessary to generate bone[1–6]; autologous bone graft is osteoinductive, osteoconductive, and osteogenic[2,5,7–12]. Because autologous bone is harvested from the patient, it is nonimmunogenic, histocompatible, and does not transmit diseases[4,8,13,14]. The mechanical properties of bone graft vary based on the donor site[7,8]. When considering the optimal donor site to acquire an autologous bone graft, surgeons must consider the size of the bone defect, properties of the selected bone graft, ease of harvest, and potential morbidity to the patient.

Iliac crest bone graft (ICBG) is the most used autologous bone graft site because it provides large quantities of bone graft and is readily accessible[1,2,10,13–15]. Additionally, ICBG can be harvested as a corticocancellous or cancellous bone graft, depending on the desired structural integrity[2]. ICBG is commonly used for nonunions, spinal fusion, fractures with significant bone loss, deformity corrections, arthrodesis, and limb salvage procedures[8,12,16,17]. Bone graft can be harvested from the anterior or posterior iliac crest; while the anterior graft site is more conveniently accessed, it is also associated with greater morbidity[13,18,19].

The purpose of this review article is to summarize harvest techniques, bone graft volume, postoperative pain, functional limitations, and complications of ICBG.

RESULTS

Surgical Approach

Preoperatively, evaluating whether the patient has undergone prior bone grafting procedures or any pelvic surgeries that might affect bone graft harvest is crucial. We recommend obtaining an anteroposterior (AP) pelvis radiograph to assess for any underlying osseous abnormalities, particularly in cases of previous pelvic trauma or surgical interventions.

Table 1. Tips and clinical pearls for the anterior and posterior iliac crest bone graft harvest.

Anterior Harvest	Posterior Harvest	Both
• Incision at least 3 cm posterior to ASIS to avoid damage to lateral femoral cutaneous nerve[10,16,25–27] • Subperiosteal dissection on iliac crest to preserve attachments of tensor fascia lata and iliacus • Graft harvest at least 3 cm posterior to ASIS to reduce risk of ASIS avulsion fracture[31]	• Incision parallel to PSIS • Blunt dissection to fascia to avoid cluneal nerves • Limit dissection posterior or inferior to PSIS to avoid sacroiliac joint or superior gluteal artery[10,30,31] • Graft harvest at least 2 cm anterior to PSIS to avoid injury to posterior spine or SI joint[30]	• Avoid incisions directly over bone • Adequate intraoperative hemostasis • Layered closure

Bone graft can be harvested from the anterior or posterior iliac crest (**Figure 1, Table 1)**. The anterior iliac crest is often more convenient due to supine patient positioning[10], whereas the posterior iliac crest is more accessible during posterior spinal fusion[11,20,21]. Some authors suggest the anterior approach is associated with higher rates of complications such as infection, hematoma, and fractures[13,18,19]. The posterior iliac crest has been associated with higher rates of chronic pain and sensory disturbances at the donor site[13,19,22]. However, Becker et al. found near equivalent pain levels between anterior and posterior harvest patients at 1 week and 6 months after surgery[15]. Studies comparing the two harvest sites have shown no significant difference in intraoperative blood loss or hospital stay[18,23], with minimal difference in harvest times. Additionally, the posterior iliac crest affords a higher volume of bone graft, making it a more desirable graft site when large amounts of bone are required[24].

Anterior Iliac Crest Approach

The patient is positioned supine with a sandbag under the ipsilateral buttock[6,25]. A small incision, approximately 2-3 centimeters in length, is made in line with the iliac crest, at least 3 cm posterior to the anterior superior iliac spine (ASIS) (**Figure 2)** to reduce the risk of ASIS avulsion fracture or damage to the lateral femoral cutaneous nerve[10,16,25–27]. Authors recommend avoiding an incision directly over bone as this increases the likelihood for wound healing complications and avoids mechanical scar irritation directly over the iliac crest[19,25,28]. Instead, some authors recommend a slightly

Figure 1. Illustration of surrounding relevant structures for anterior (A) and posterior (B) iliac crest harvest sites. Created using BioRender.com.

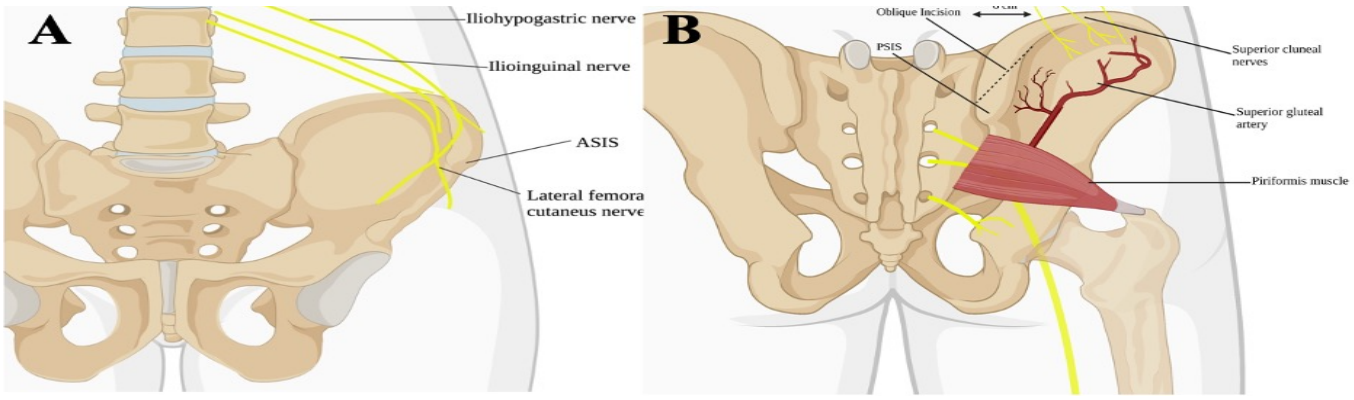
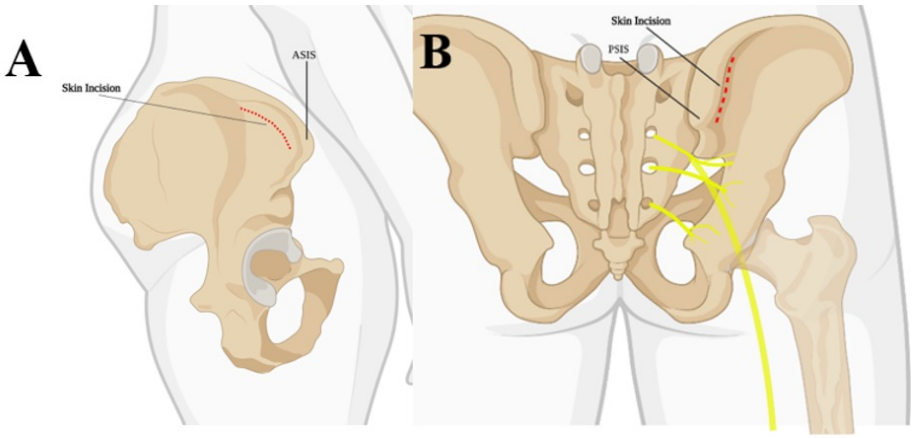
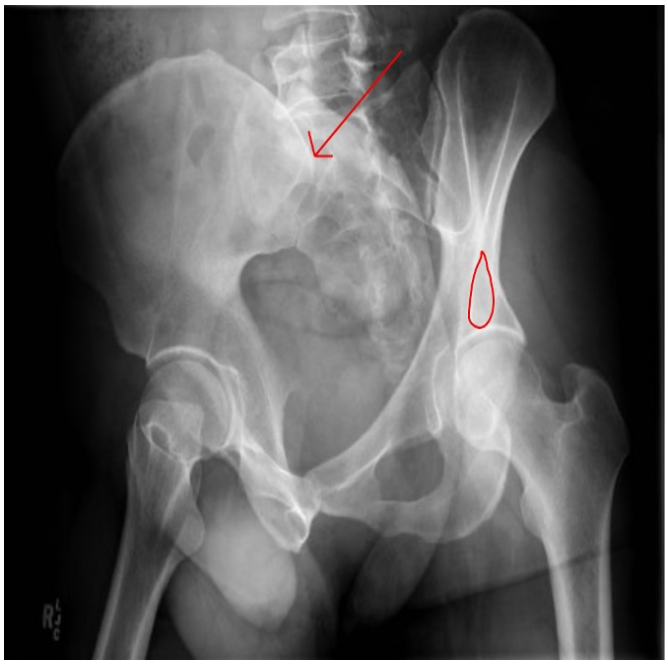


Figure 2. Illustration depicting location for anterior (A) and posterior (B) skin incisions for graft harvest. Incisions directly over bone should be avoided, where possible. Created using BioRender.com



distal incision so when pulled cephalad, the incision will be centered over the iliac crest[19]. Dissection is continued down to fascia and fascia incised at the fascial plane where the tensor fascia lata and abdominal oblique muscles join[26,28]. Soft tissue dissection is then continued subperiosteally on the iliac crest, allowing the muscular attachments of the tensor fascia lata and iliacus muscles to remain intact[27,28]. The remainder of the dissection depends on the type of graft harvested.

Figure 3. The obturator oblique or "teardrop" view is used to localize the contralateral PSIS when it is unable to be palpated. The arrow indicates PSIS.



Posterior Iliac Crest Approach

The patient is positioned prone, and the posterior superior iliac spine (PSIS) is localized either via palpation or fluoroscopically by obtaining the tear drop view on an obturator oblique view of the pelvis (**Figure 3**)[29,30]. The incision is made parallel to PSIS, taking care to avoid cluneal nerves in the subcutaneous layer, and continued down to fascia[18,30,31]. Blunt dissection is typically utilized until fascia of the gluteus maximus and internal oblique is visualized to avoid damage to the cluneal nerves[32]. Fascia is incised linearly over PSIS. Subperiosteal dissection is performed to avoid disrupting the lumbar fascia over the medial iliac crest[33]. Dissection posterior or inferior to the PSIS should be limited to avoid violating the sacroiliac joint or superior gluteal artery[10,30,31].

Graft Harvest

Structural property is dependent on the type of graft harvested. Cancellous bone grafts are osteoinductive, osteoconductive, and osteogenic[2,5,7–12]. While cancellous bone grafts lack initial structural support, strength increases over time as the graft incorporates[4,7,8,10] . Corticocancellous grafts can be unicortical, bicortical, or tricortical, and have the distinct advantage of providing

immediate structural support[2]. These can be incorporated initially via press-fit technique or internal fixation using various methods which affect its immediate strength. The strength of cancellous and corticocancellous grafts increases as bone mass accumulates and remodeling occurs[4]. An illustration of iliac crest cancellous and corticocancellous bone graft option is depicted in **Figure 4**.

Cancellous Bone Graft

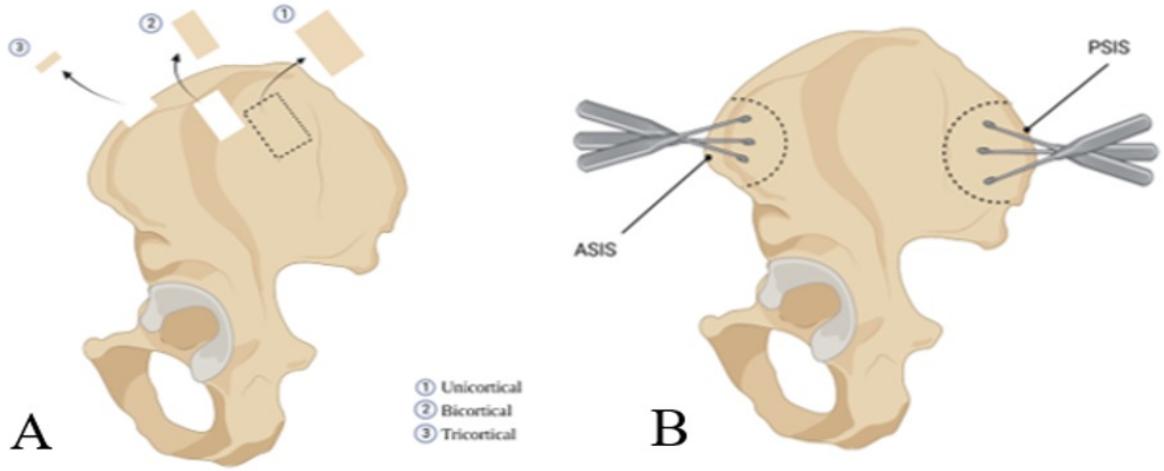
Cancellous bone graft, whether obtained from anterior or posterior iliac crest, is harvested via a corticotomy with a surgical burr or osteotome, leaving the inner and outer cortical iliac bone intact, and is then harvested using currettes, hand gouges, or rongeurs[1,12,16,19,25,27,28]. Special care must be taken to follow the course of the ilium in order to prevent fracture[19]. The trap-door technique has been described for both the anterior[31] and posterior[27,31] iliac crest, which involves elevating a bone flap in the iliac crest that is repaired after graft harvest. Alternative harvest techniques have also been described[17,28,34,35]. Trephinated curettage or core reamers allows for less soft tissue dissection and might decrease postoperative pain associated with graft harvest[35,36]. Others have described harvesting cancellous graft using a 40–46-millimeter acetabular reamer placed against the ilium at the gluteal ridge[34]. The acetabular reamer technique might afford a larger quantity of bone graft at a cost of greater morbidity than traditional techniques[34].

Corticocancellous Bone Graft

Alternatively, if corticocancellous graft is desired, the iliacus muscle can be elevated from the inner table of the ilium and a microsagittal saw or osteotome can be used to harvest the desired graft[26,28]. Corticocancellous bone graft can be harvested as unicortical, bicortical, or tricortical graft depending on the desired structural support.

Unicortical or bicortical bone grafts are harvested using a subcrestal window technique, which requires stripping of musculature from the inner and outer table of the ilium[31]. Unicortical and bicortical grafts do not include the iliac crest (**Figure 4**). Traditionally, unicortical bone grafts are harvested from the outer table of the ilium, taking care not to penetrate the inner table[28,31]. Bicortical

Figure 4. Illustration of the difference between corticocancellous (A) and cancellous (B) iliac crest bone graft. Unicortical (1A) and bicortical (2A) bone grafts are obtained through subcrestal windows; unicortical bone grafts are typically harvested from the outer table of the ilium and bicortical grafts include the inner and outer table of the ilium. Tricortical (3A) grafts are obtained from the iliac crest at least 3 centimeters posterior to the anterior superior iliac spine (ASIS). Created using BioRender.com.



bone grafts include the inner and outer table of the ilium[28,31].

Tricortical and bicortical grafts are commonly used for anterior interbody spinal fusion surgery, as the added cortex provides substantial structural integrity[31]. Tricortical bone grafts include inner and outer iliac tables and the iliac crest. Tricortical bone graft is harvested via two parallel cuts through both tables of the ilium[28,31]. When harvesting from the anterior iliac crest, cuts should be at least 3 centimeters posterior to ASIS[31]. Posteriorly, cuts should be made at least two centimeters anterior to PSIS to avoid injury to the posterior spine or sacroiliac joints[30]. An osteotome or reciprocating saw can be used to make cortical cuts, though some surgeons prefer the saw, as osteotomes may weaken the graft[28,31,37].

While multiple cortices increase graft structural integrity, it is important to consider consequences of soft tissue stripping. Chen et al. compared inner-table only and inner-outer table exposure techniques for anterior tricortical bone graft harvest in pediatric patients, and found exposure of only the inner table of the ilium resulted in faster healing of the donor-site defect[38]. The authors hypothesized that limited exposure preserves periosteum and superior gluteal artery vascularity, thereby hastening donor-site healing[38]. Exposure of both tables of the ilium could worsen the cosmetic appearance due to lower healing potential at the harvest site, though this has not been studied. Moreover, additional soft tissue stripping could predispose patients to wound healing and pain issues. Soft tissue stripping should be minimized wherever possible.

Iliac crest bone marrow aspiration has also been described, though iliac crest aspirate is not osteoconductive[39]. Bone marrow aspirate decreases donor site morbidity as it is performed through a percutaneous approach through an anterior or posterior approach[40]. Anteriorly, a small 5 mm incision is made 3-4 cm posterior to ASIS and the trocar and cannula are inserted between the inner and outer table[38]. Through a combination of rotation and tapping, the trocar is advanced no further than 4-6 cm, and the trocar needle is exchanged with a syringe[38]. The syringe can be rotated 45 degrees at a time, allowing for up to 50-60 mL of bone marrow aspirate to be obtained from a single incision[38]. Posteriorly, a starting point is identified between the medial and lateral borders of the iliac crest, and the trocar is inserted in a similar manner, aiming 30 degrees laterally and 20-30 degrees inferiorly and advanced 5-7 cm[38]. Iliac crest aspiration has been shown to be safe with minimal morbidity[39]. Complications for bone marrow aspiration are similar to open graft harvest, including pain, hematoma, seroma, wound complications, infection, vascular injury, and perforation into the peritoneal cavity, although rates are significantly lower following aspiration[38]. Bone marrow aspirate is used for small (less than 1 cm) defects, though it can be augmented with cancellous bone allograft or calcium phosphate to provide structural support for larger defects[17,40]. A retrospective cohort study by Lin et al. showed no significant difference in union rate between bone marrow aspirate and ICBG to treat diaphyseal nonunions[40]. The ICBG included in this study included both cancellous graft, harvested using a cortical window, or corticocancellous graft, harvested using a small diameter reamer based on surgeon preference and required graft volume[40].

Bone Graft Volume and Graft Storage

Surgeons must consider the volume of bone graft required when selecting a donor site, as each donor site has a finite supply of available graft. Moreover, the volume and quality of bone graft available varies with

age and sex[41]. Less bone graft can be harvested from the anterior iliac crest than the posterior iliac crest[10,15,18,42]. Traditionally, posterior ICBG is utilized when over 20 cm^3 of bone graft is required[10].

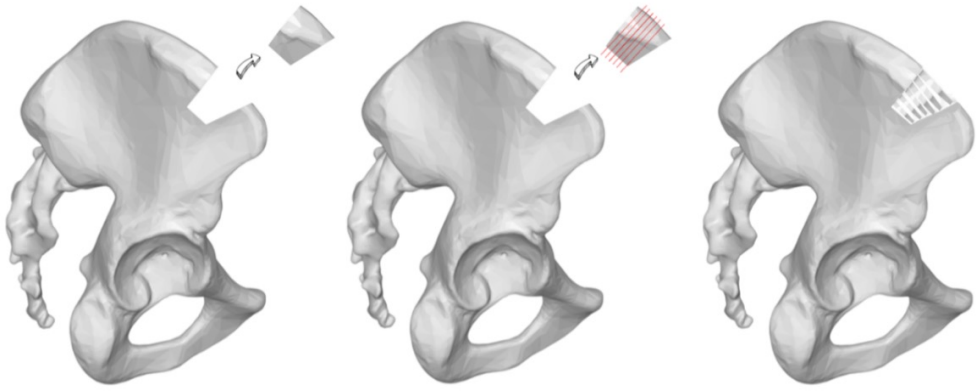
Anterior ICBG graft volume has been reported between 4.1 cm^3 to 54.3 cm^3 [18,43], while posterior ICBG volume averages between 18 and 55.1 cm^3 [15,18]. Kessler et al. reported an average graft volume of 9 cm^3 from the anterior iliac crest, compared to 25.5 cm^3 from the posterior iliac crest[42]. Hall et al. reported average cancellous bone volume obtained from the anterior iliac crest of elderly cadavers was less than half the average volume from the posterior iliac crest (12.9 cm^3 vs 30.3 cm^3)[44]. Becker et al. reported mean graft volumes for the anterior and posterior approaches were 12 cm^3 and 18 cm^3, respectively[15]. Ahlmann et al. reported significantly higher graft volumes (54.3 cm^3 for anterior harvest and 55.1 cm^3 for posterior harvest), though authors included cortical bone in their graft preparation, which likely increased graft volume[18].

Proper graft handling is crucial to maintain viability of harvested cells and optimize outcomes. Once harvested, autologous bone graft should be stored in a moist environment. While some recommend 5% glucose solution or 0.9% saline[45,46], Bloomquist et al. stored cancellous bone graft in blood-soaked gauze to preserve graft viability[30]. Bone graft should not be left open to air, as dry storage impairs cellular metabolism and decreases cell survival[30,45,46]. Most authors agree graft should be expeditiously implanted once harvested[45,46].

Closure Techniques

One of the most common complaints after ICBG is poor cosmetic appearance from the defect in the iliac crest[28]. There has been increased attention towards improving cosmesis with reconstruction at the harvest site and, potentially, postoperative pain[1,6]. Dusseldorp et al. described injecting calcium phosphate cement into the donor site defect, though this did not reduce the incidence of the persistent postoperative donor site[1]. Gil-Albarova published a small case series on a technique to fill the donor site defect by building a transverse “fence” of tricortical autograft chips (**Figure 5**), and reported high patient satisfaction with no complications[6]. These tricortical chips are obtained from the posterior lateral wall of the bone defect and are impacted in place[6]. The

Figure 5. Donor site reconstruction using a transverse fence of tricortical bone as described by Gil-Albarova[6]. Created using BioRender.com.



use of custom titanium plates[47] or Vicryl mesh[48] to decrease the risk of hernia has also been described. Others describe careful repositioning and repair of the osteoplastic flap to minimize donor site deformity[25,27]. Regardless of closure technique, patients may resume immediate weight-bearing unless a concurrent lower extremity injury precludes them from doing so[19,49].

Adequate intraoperative hemostasis minimizes the risk of postoperative hematoma and infection. Techniques to obtain hemostasis include packing the harvest site with lap sponges[10,31], injecting thrombin into the iliac wing[10], Gelfoam (Upjohn, Kalamazoo, Michigan)[10,29], thrombin-soaked sponges[19], or bone wax[26,30].

Once hemostasis has been obtained, layered closure minimizes potential complications[50]. The apophysis and fascia should be repaired where possible to restore bone contour and decrease dead space. Some recommend using resorbable suture for fascial closure, such as 0-Vicryl or 0-chromic gut[6,10,25,29], while others describe using nonabsorbable suture, such as a 0-ethibond[19]. After fascial closure, the harvest site can be injected with local anesthetic to assist with postoperative pain[19,29], though Suda et al. reported local anesthetics did not influence postoperative pain[16]. The addition of epinephrine to local anesthetic can assist with hemostasis[19].

While some authors advocate using a suction drain,[6,10] this is debated[25,26]. In a prospective randomized study, Sasso et al. concluded the use of a drain did not influence the complication rate, suggesting routine use of a drain is not necessary[51]. A consecutive case series conducted by Banwart et al. also found no significant correlation between drain use and complication[50]. Other authors have proposed the overall low prevalence of wound complications and postoperative hematomas is due to standardized drain protocols, however, these studies lacked a comparison group to provide statistical support to these claims[52,53]. Without standardized drain protocols, complication data can be affected by selection bias, as Younger and Chapman noted higher complication rates associated with drain placement confounded by the use of drains for more extensive incisions and when hematoma formation was anticipated[54].

Superficial wound closure is performed according to surgeon preference. Most authors prefer resorbable sutures for superficial wound closure[19,25]. Skin closure with a running, subcuticular resorbable suture is felt to produce a more cosmetic scar[19,25,26]. Interestingly, Sasso et al. concluded the type of wound closure did not influence the overall complication rate[21].

Complications

Although the anterior graft site is more conveniently accessed, anterior ICBG harvest is associated with a higher complication rate (**Table 2**)[13,18,19].

Postoperative Pain

Postoperative pain after harvest of ICBG is common[18,42,52,53]. Several studies report more significant and greater pain duration following anterior harvest than posterior harvest[18,42]. Persistent donor site pain is poorly defined, as some studies report persistent pain as pain present at 6 weeks, 3 months[1], 6 months, 1 year[5], or 2 years[54]. Armaghani et al. reported patients experience the first significant decrease in donor site pain at 6 weeks, but do not experience another significant decrease until 1-year post-surgery[26].

Heneghan et al. reported over 90% of patients experienced graft site pain for over 1 month post-operatively, and the mean duration of pain was 13.3 weeks[23]. A systematic review performed by van de Wall

Table 2. Summary of major and minor complications after anterior and posterior iliac cortical bone graft harvest.

Complication	Anterior ICBG Harvest	Posterior ICBG Harvest
Pain	10% of patients reported donor site pain after 1 year.[26,53]	14.3-40.9% of patients reported donor site pain after a minimum follow up of 2 years.[67]
Nerve injury	Up to 8% of patients reported persistent LFCN related numbness.[18,25]	Injury to the superior cuneal nerves is reported to cause transient or permanent numbness over the buttocks.[64]
Gait Disturbance	42-46% of patients experienced temporary gait disturbance.[15,60]	6-35% of patients experienced temporary gait disturbance.[15,60]
Blood vessel injury	None identified	0.7% of patients experienced an injury to the superior gluteal artery.[25]
Fracture	2% of patients experienced stress fracture of the anterior ilium[60] and 0.5% of patients experienced an iliac wing fracture.[9]	No patients experienced a fracture in a systematic review of 1909 posterior ICBG harvests.[13]
Infection	1.79-2% of patients experienced an infection (superficial or deep infections).[13,26]	0.94% of patients experienced an infection (superficial or deep infections).[13]
SI joint instability	None reported	SI joint stability following posterior ICBG is rare but has been reported in case series and reports.[65,66]
Intra-abdominal injury	0.5% of patients experienced small bowel herniation through donor defect after massive tricortical bone graft.[9]	None reported

et al. reported 14% of patients had chronic pain after ICBG harvest, defined as pain at the end of study follow-up[55]. The incidence and severity of donor site pain decrease with time. Goulet et al. surveyed patients who underwent ICBG harvest and found 38% had donor site pain 6 months after surgery, and 19% reported persistent pain at 2 years[54]. Others reported 90% of postoperative pain after harvest resolves within 3 months[53]. Dusseldorp et al. found 5 of 12 patients who underwent anterior ICBG harvest had donor-site pain after 3 months, but all pain scores were less than or equal to 2 out of 10[1]. Reported rates of donor site pain exhibit high variability, likely stemming from differing indications and length of follow-up. Nevertheless, donor site pain remains a significant concern for both patient and providers.

Harvesting larger volumes of bone graft increases donor site morbidity[16,18]. Theoretically, smaller bone graft harvests involve less injury to the musculature and periosteum, thereby decreasing pain. Female sex and obesity might also be risk factors for protracted pain after ICBG harvest[11]. Additionally, Goulet et al. noted patients who underwent ICBG harvest for spine surgery had higher incidence of donor-site pain[54].

Multiple interventions have been trialed to improve postoperative pain, with varying efficacy. Singh et al. continuously infused 0.5% Marcaine at ICBG harvest site and found improved outcomes in the immediate postoperative period[56]. Interestingly, patients who received the perioperative infusion reported lower pain scores and less painful days per month at 4 years post-surgery[56]. This contrasts with Morgan et al., who reported more pain in patients who received a bupivacaine infusion at the surgical site than those who did not, and no difference in narcotic medication consumption between the two groups[57]. Alternatively, Wai et al. compared intraoperative morphine infiltration at ICBG harvest site to placebo and found no difference

in pain at 1-year postoperatively[58]. Intraoperative infiltration of local anesthetics or opioids is likely short-lived and does not appear to improve patient pain levels consistently. Black et al. demonstrated the transversalis fascia plane block provides adequate analgesia after anterior ICBG harvest[59]. The frequency of regional nerve blocks after orthopaedic procedures continue to increase, and additional studies are necessary to determine the efficacy of these techniques for ICBG harvest.

Gait Disturbance

Gait disturbances after ICBG occur between 6-46% of patients[15,60]. Fortunately, gait disturbances often resolve within the month after surgery and most patients return to full activity within 4-6 weeks regardless of the procedure[2,43]. Patients who underwent anterior ICBG harvest are more likely to have a gait disturbance, and when present, it lasts longer than posterior ICBG harvest. Becker et al. reported a gait disturbance in 46% of patients following anterior ICBG harvest, compared to 35% following posterior ICBG harvest[15]. Moreover, 65% of patients in the anterior group required crutches compared with 25% in the posterior group[15]. Marx and Morales found 42% of patients who underwent anterior harvest had a noticeable limp on postoperative day 10 compared with 6% in the posterior harvest[60]. By postoperative day 60, no patients were limping in the posterior group, compared with 15% of patients in the anterior group[60]. However, while most patients recover well and return to baseline activity, up to 15% of patients report subjective difficulty walking 1 year after graft harvest[20].

Minor Complications

Younger and Chapman define minor complications as those that do not cause permanent impairment and resolve with minimal treatment[52]. Common minor complications after ICBG include minor wound complications (i.e., small hematoma, seroma), local numbness, superficial infection, and delayed wound healing[2,13] Rates of minor complications after anterior ICBG harvest range from 0.8% to 27%[52,61]. Younger and Chapman reported a 25% and 27% minor complication rate when harvesting from the outer and inner table of the anterior iliac crest, respectively[52]—rates of minor complications after posterior ICBG harvest range from 0% to 13%[18,52].

Superficial wound infections or dehiscence occur in approximately 5% of patients undergoing ICBG harvest[11,26,55]. Females, obese patients, and patients with significant medical comorbidities are at increased risk for superficial wound complications[11]. Incisions directly over the iliac crest should be avoided to decrease the risk for wound complications. Bierne et al. recommends a laterally based incision distal to the iliac crest to avoid a scar directly above the crest and produce a more cosmetic scar[25].

Major Complications

Younger and Chapman define major complications as those that require additional days in the hospital, surgical intervention, permanent disability, or long-term sequelae[52]. Major complications are less common than minor complications and include deep infections, fractures, neurovascular injury, abdominal hernia, ureteral injury, sacroiliac injury, and hematomas[13,52]. The rate of major complications is higher with the anterior approach, according to Ahlmann et al. (8% versus 2%)[18].

Lateral femoral cutaneous nerve (LFCN) injury is a complication specific to the anterior ICBG harvest, though the iliohypogastric and ilioinguinal nerves are also at risk for injury[31,55]. The LFCN courses under the inguinal ligament just inferior to ASIS, though in some patients an aberrant LFCN exits superior to ASIS,

placing it at higher risk for injury[31]. Ahlmann et al. reported persistent LFCN numbness in 8% of patients[18]. Beirne et al. reported 3 patients (1.9%) with altered LFCN sensation, though two patients had resolution of their symptoms without intervention[25].

Fractures of ASIS or the iliac wing have been reported after anterior iliac harvest and are usually treated conservatively[5,9,60]. Marx and Morales published a case series of 50 anterior ICBG harvest for facial reconstruction and reported 1 stress fracture of the anterior ilium which was treated conservatively[60]. Arrington et al. retrospectively reviewed 414 ICBG harvests and reported 2 iliac wing fractures[9]. Both fractures were treated without surgery, and the authors noted the graft harvest site was too anterior in both cases[9]. Anterior graft should be harvested at least 3 centimeters posterior to ASIS to minimize risk for fracture[31].

Although rare, abdominal contents can herniate through significant defects in the iliac wing donor-site. Patients typically present with abdominal pain and a mass[9,62]. The treatment approach depends on whether the patient exhibits signs of bowel obstruction or incarceration. In cases without these symptoms, conservative management is usually employed[9], while surgical repair is the preferred course of action when such signs are evident[62]. Heneghan et al. reported on a patient who developed a bowel perforation from a small fragment of the ilium three days after iliac crest graft harvest[23]. The patient's bowel perforation was surgically repaired, and she otherwise recovered without further sequelae[23].

Posterior Harvest Complications

Complications specific to posterior ICBG harvest include injury to the superior gluteal artery, damage to cluneal nerves, and injury to the sacroiliac joint[9,18,30,31,52]. Additionally, there is a published case report on a traumatic arteriovenous fistula and ureteral injury after posterior ICBG harvest[63].

The cluneal nerves are branches of the L1-L3 dorsal rami and provide sensation to the buttocks[64]. The cluneal nerves run over the iliac crest just lateral to PSIS and can be injured during posterior ICBG harvest[18,30]. Arrington et al. reported three cases of superior gluteal artery injury during posterior ICBG harvest, possibly due to retractor placement in the sciatic notch[9]. In addition to vigilant retractor positioning, surgeons should avoid harvesting posterior ICBG greater than 4 cm distal from PSIS to avoid violating the sacroiliac joint or injuring the superior gluteal artery[33].

Violating the sacroiliac joint during posterior ICBG harvest can cause instability, pain, or arthritis[31]. Sacroiliac instability after posterior ICBG harvest is rare, and likely results from inadvertent damage to the sacroiliac ligaments during graft harvest. The existing literature is limited to small case series or case reports[65,66].

Cost Analysis

Surgeons should be familiar with the cost associated with utilization of ICBG. Processing the instrument tray necessary for grafting and the operating room time utilized for positioning, setup, and harvest are all considered when assessing cost and vary across institutions. Dawson et al. reported a $100 cost to process instrument trays necessary for ICBG harvest at their institution; on average, anterior ICBG harvest took 33 minutes, and posterior ICBG took 40 minutes[67]. In their study, they quoted 10 minutes of operating room time at $890, lowering the cost of anterior ICBG compared to posterior ICBG ($3,037 vs $3,660)[67]. Notably, the operating room time cost varies

considerably; Evans et al. noted an average cost of $46.04 ± $32.31 per minute, underscoring the substantial cost differential amongst different institutions[68].

Another popular option for autograft is the Reamer–Irrigator–Aspirator (RIA; Synthes, West Chester, PA). The cost of RIA includes both the equipment and the required operating room time needed to perform the harvest. Dawson et al. reported that RIA's setup cost was $738, which is notably higher than the $100 setup for ICBG[67]. However, compared to anterior and posterior ICBG, RIA had shorter operating room time by 3.8 minutes and 11.2 minutes, respectively[67]. Nonetheless, anterior or posterior ICBG can be more cost-effective in certain situations, especially when small graft volumes are required and patient repositioning is avoided.

Synthetic bone graft substitutes have increased over the last several decades. The benefits of synthetic bone graft substitutes include immediate availability and the elimination of the associated costs. There are many commercial options for synthetic graft substitutes, allograft, and demineralized bone matrix. Prices vary based on quantity but range from $200-400 per one cubic centimeter of demineralized bone matrix and $464-472 per one cubic centimeter of cancellous allograft[69]. While synthetic bone graft substitutes might be cost-effective with small graft volumes, this quickly diminishes and surpasses the cost of ICBG when higher volumes are required. Moreover, prices are negotiated by individual institutions' surgical centers. Lower-volume centers often incur higher prices, whereas higher-volume centers can negotiate lower prices. Lastly, synthetic bone graft substitutes have a finite shelf-life, which could impact their availability. Surgeons must be aware of what synthetic bone graft substitutes are available at their institution and understand their cost relative to autograft.

CONCLUSION

The iliac crest is a common harvest site for autogenous bone graft due to its expendability and large quantities of available graft. Furthermore, the iliac crest is readily accessible in both supine and prone positions. ICBG can be harvested as corticocancellous or cancellous bone graft, depending on the structural integrity desired. The most common complications associated with ICBG harvest are donor site pain and cosmetic deformity due to the iliac crest defect. Major complications, though rare, include deep infection, fracture, and neurovascular injury. Surgeons must be familiar with relevant anatomy, harvest techniques, bone graft volume, and potential complications associated with iliac crest bone graft to decrease morbidity.

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