Chapter 9

Vascular Injury in Total Hip Replacement: Management and Prevention

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Additional information is available at the end of the chapter

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Abstract

This chapter analyzed the vascular complications in total hip replacement. Vascular injuries are the uncommon but well recognized and serious issue. During total hip replacement, laceration of major blood vessels has been reported which even cause morbidity and mortality. The injury to vascular structures occurs due to the placement of screws to fix acetabular components, structural grafts, and protrusio cages or rings. Massive hemorrhage resulting in immediate exsanguination may be caused due to the damage of any of these vessels by processes such as drilling, reaming, retraction, or dissection. The majority of these vascular injuries might be better prevented or even more proficiently treated by comprehensive preoperative assessment, better instrumentation, and careful postoperative monitoring.

Keywords: vessel injury, uncemented total hip replacement, reaming, bone screws, acetabulum, iliac artery, acetabular cup, obturator artery, reaming

1. Introduction

This chapter gives an etiology, management, and prevention of common injuries that occur at the time of total hip replacement surgeries or postoperative period. A total hip replacement has become one of the most successful procedures with minimal complications and long-term result [1]. According to the data published by various major national and international joint registries, an increasing number of total hip replacements are performed each year. The incidence of vascular injury occurs at the time of hip surgery or immediate postoperatively or in the late postoperative period, which is quite rare (0.2–0.3%), but the inevitable and serious issue may cause morbidity and even mortality [1, 2]. The most common pattern of vessel injuries include lacerations, pseudoaneurysms, thromboembolic and arteriovenous fistula [3–5].

Contiguous arteries to the acetabulum that are susceptible to be injured during total hip replacement are mostly branches of common iliac vessels; external iliac vessels, obturator vessels, superior and inferior gluteal artery, and internal pudendal arteries and veins as shown in **Figure 1** [6–12]. Indeed, many vascular structures surrounding the acetabulum may be injured by direct and indirect trauma have been reported [12, 13]. In particular, the primitive cause of injuries includes reaming during acetabular preparation, and retractor induced injury, drilling holes for fixation of screws in cementless acetabular cups, excessive traction in surgery, postoperative cup migration (**Figure 2a** and **b**). Also, cement erosion, excessive local heating by methyl methacrylate in cemented total hip replacement are further reasons of occurrence of arterial injuries during total hip replacement [4, 14–20]. However, there are many reported reasons in which symptoms of vessel injury were not evident. The possible reasons might be bone fragments or contamination caused due to soft tissue defect, result in infections [21].

Vessel injuries giving immediate symptoms of total hip replacement are the severe hemorrhage. The most common ischemic symptoms in the delayed postoperative period include pain, the decrease of hemoglobin, swelling, reduced blood pressure and hypovolemic shock [1, 2, 4, 6, 10, 11, 22, 23]. Other presenting signs and symptoms of vessel injury in revision surgeries include excessive bleeding, loss of pulse and instability during extraction of hip prosthesis [19].

In some reports, gender biasing has also been observed as one of the causes of vessel injury. In several retrospective studies, the female dominance of vessel injury as compared to male (3:2) has been confirmed [1, 4, 5, 16, 24].

At present, the participating physicians in total hip replacement are increasing, and indeed, vessel injury is a credit to those who are engaged in these types of surgeries. The relationship of pelvic vascular structures surrounding the acetabulum has been described in several studies [7, 9, 25]. Currently, substantial work by researchers has been carried out to visualize the

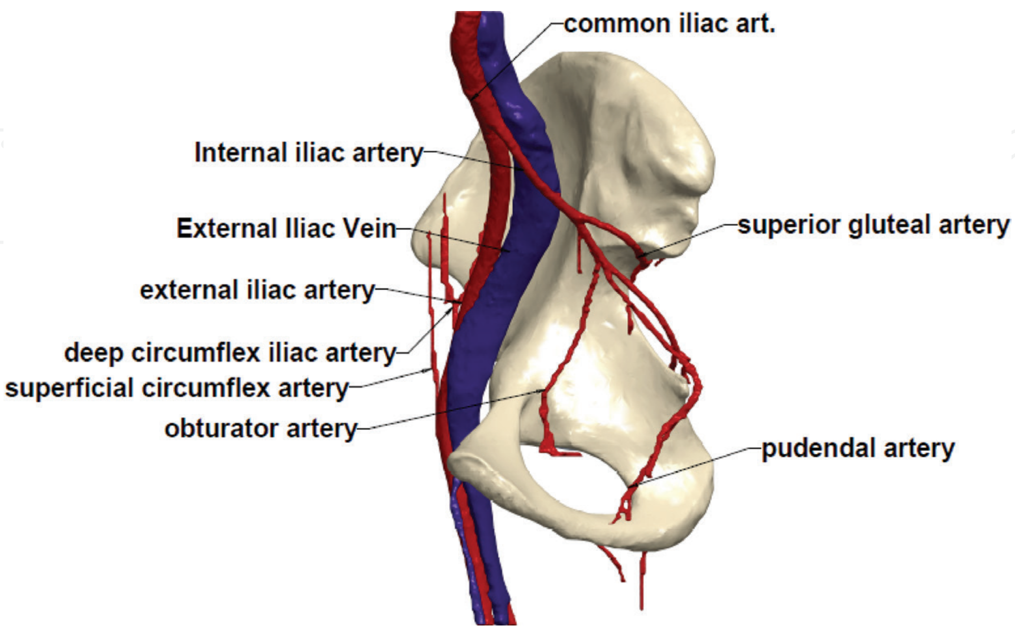

Figure 1. Three-dimensional construction of pelvis and vessel structures using computed tomographic images.

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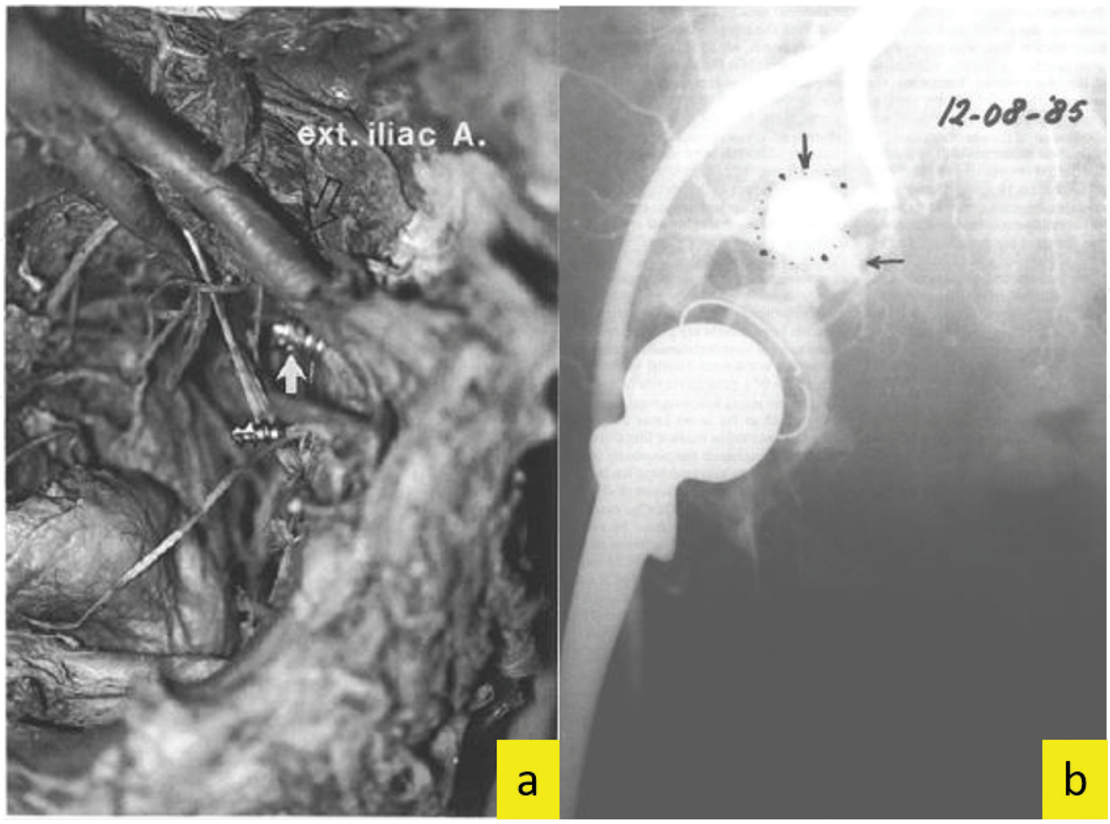

Figure 2. Vessel injury. (a) Photograph illustrating inserted acetabular screw close to external iliac artery and vein (arrow) (reprinted with permission from Hwang [25]). (b) Postoperative false aneurysm of superior gluteal artery (circled lines) by protruding cement to fix acetabular component (horizontal arrow) (reprinted with permission from Bakker and Gast [10]).

detailed vascular structures surrounding the acetabulum with the use of three-dimensional computed tomographic angiography (3DCT-A) [26–30]. These studies identified the actual distance of vessel structures to the osseous surface of the acetabulum to prevent the injuries caused by fixation of screws in cementless total hip replacement.

2. Prevention of vascular injuries

2.1. Obey quadrant system

Earlier, in continuation to prevent these injuries during fixation of acetabular screws, a simple method of acetabular quadrant system was described by Wasielewski et al. and accepted widely till date [9]. Various anatomical studies have shown the fixation of screws in cementless primary total hip replacement, particularly in revision surgeries being most prominent reason for vascular injuries.

Wasielewski et al. defined the acetabular-quadrant system for managing safe placement of screws during primary and revision total hip replacement surgeries. The quadrant system is proposed to explain the relationship between the osseous structure of acetabulum and surrounding vascular structures to prevent the vascular structures.

Acetabular quadrant system consists of four parts of acetabulum by dividing acetabulum with two mutually perpendicular lines. The first line A originates from the anterior superior iliac spine (ASIS) and passes straight to the center of the acetabulum, dividing the acetabulum into two halves and named collectively as anterior and posterior quadrants. The second line B originates from center of acetabulum and perpendicular to the first line, resulting in the two superior and inferior halves (**Figure 3**). To this end, these two perpendicular lines together form four quadrants by intersecting each other at the center of acetabulum, which is collectively named as an anterior superior quadrant, anterior inferior quadrant, posterior superior quadrant and posterior inferior quadrant. Most of the work published on vascular injury has been carried out on the cadaveric bone; the authors tried to give a clear picture of quadrant system by developing the three dimensional computational model of the pelvis and surrounding vascular structure with the help of angiographic computed tomography (A-CT). In the development of three-dimensional models of vascular structures, some of the arteries and veins are not visible because of imaging limitations of computed tomographic machine.

Quadrant system specifies the safe zones to fix the proper sized acetabular screws that are carefully considered at the time of total hip replacement surgery. The relationship between vascular structures and four quadrants with lines passing and center of acetabulum respectively mimic the safe and dangerous zones, which are as follows:

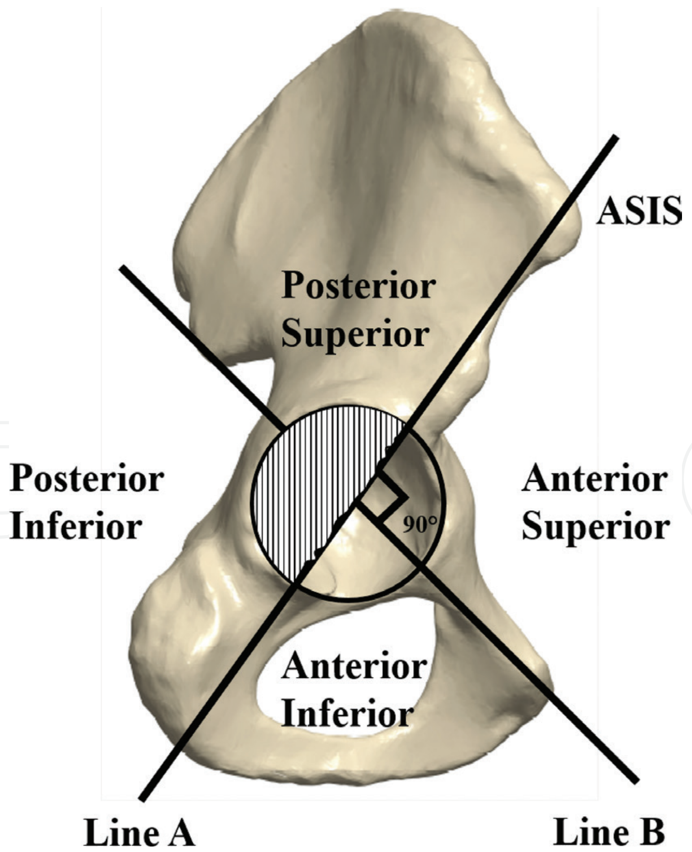

Figure 3. Demonstration of quadrant system used for placement of screws in total hip surgery.

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2.1.1. Anterior-superior quadrant

This quadrant contains the external iliac artery and vein. The acetabular screws fixed in this quadrant will be directed towards these vessels. However, it was found that external iliac vein is lying down in more medial position than an artery and therefore is in more risky as compared to the artery.

2.1.2. Anterior-inferior quadrant

Obturator artery is present in this quadrant, and the bone stock is thin in respect of other quadrants. This order will increases the possibility of vessel injury during screw placement.

2.1.3. Posterior-superior quadrant

From the previous literature of dissection and a considerable amount of three-dimensional studies, it is evident that superior posterior quadrant has good bone stock. This quadrant contains the superior gluteal artery and vein, as they pass to the pelvis through the greater sciatic notch. The proper sized screw may be considered for safe placement as the bone stock in the central zone of this quadrant is more than 25 mm.

2.1.4. Posterior-inferior quadrant

Screws that are fixed in this quadrant are directed towards inferior gluteal and pudendal vessels. The quadrant is considered safe for screw placement as the central zone has a good bone purchase, and therefore a proper size of a screw may not touch the vessel structure thereby preventing the vessels from injury.

2.1.5. Center of the acetabulum

Line A and line B intersect each other at the center of the acetabulum. This position is very close to the obturator artery and is always avoided for placement of screws.

However, screws placed along line A in the superior portion of the acetabulum are directed towards the external iliac artery and may not be appreciated. Screws placed along line A in the inferior portion of acetabulum lie close to obturator vessel.

From the above discussion on quadrant system, it must be pointed out that external iliac vessels, obturator vessel and superior gluteal artery seem to have the most frequent injury. The anterior quadrant must be avoided for the placement of screw during total hip procedures, as these vessels mostly lie in this quadrant. In the exposure of posterior quadrants, the superior posterior quadrant is typically safer for proper sized screw placement as it has good bone purchase regardless of the presence of vessel structures.

In view of above, to give a clear picture of the quadrant system to prevent vascular structures from injury, the acetabular cups with 12 holes and additional central screw fixation is demonstrated along with vessel structures in **Figure 4**.

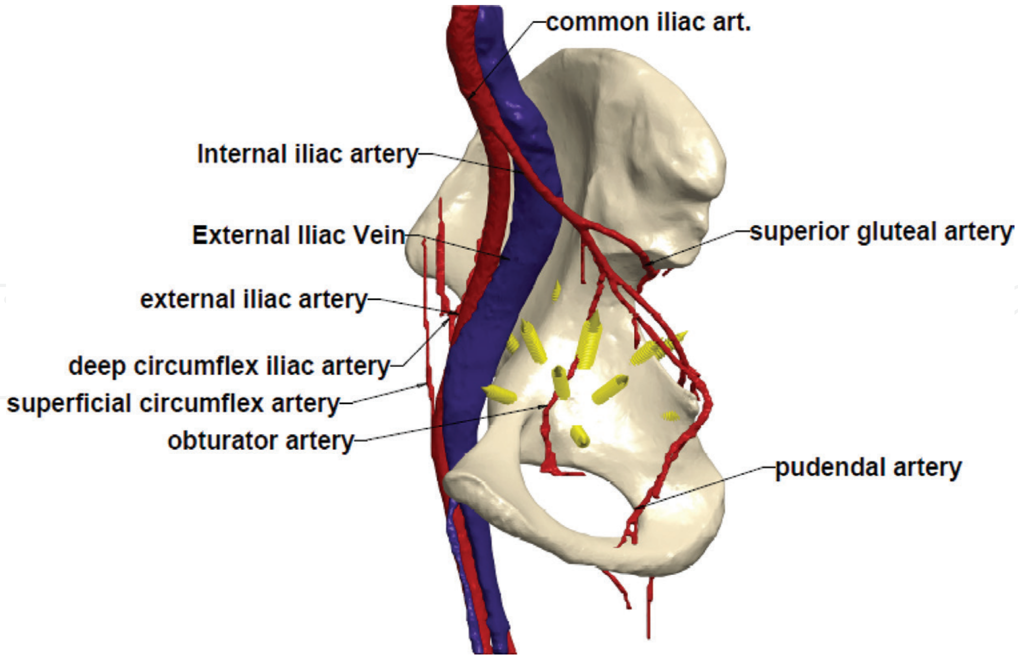

Figure 4. Visualization of vessels surrounding the pelvis which are prone to injury from screw placement.

2.2. High hip center

In cases of high hip center, the quadrant system serves as in normal hips but it is constructed in different ways. In the high hip, posterior superior and inferior posterior quadrants are found safe for screw placement with good bone stock at the periphery of the acetabulum as shown in **Figure 5** [31].

Besides, a rare case of the aberrant anatomy of vessels was found, in such cases, care must be taken during fixation of screws as they are more susceptible to injury [9, 32–34].

In the cases of revision surgeries where there is a bone loss in posterior quadrants, placement of screws is necessary in anterior quadrant. To place proper sized screws in the anterior columns, Lewallen proposed a technique in which screws and drill bits may be passed by visual perception and palpation of the careful dissection of soft tissues in anterior quadrant [7].

The quadrant system described by Wasielewski et al. is prevalent among total hip arthroplasty surgeons, until the normal hips are taken into account. In the technical demand for total hip replacement of Crowe type-IV developmental dysplasia, the posterior superior quadrant system is condemned. The reason behind this is that center of the acetabulum is shifted anteroinferiorly in the hip with a high, complete dislocation (**Figure 6**). Screws lying in the safe quadrant (proposed by Wasielewski et al. for normal hips) may frequently injure the obturator blood vessels. In such type of cases, modified quadrant system must be used on surgeon recommendations [26].

2.3. Acetabular retractors positioning

Retractors are placed around the acetabulum for proper exposure of acetabulum during total hip arthroplasty. It has been found that surgical approaches adopted by surgeons, are not only the appropriate causes of injury. Consequently, appropriate retractor positioning and

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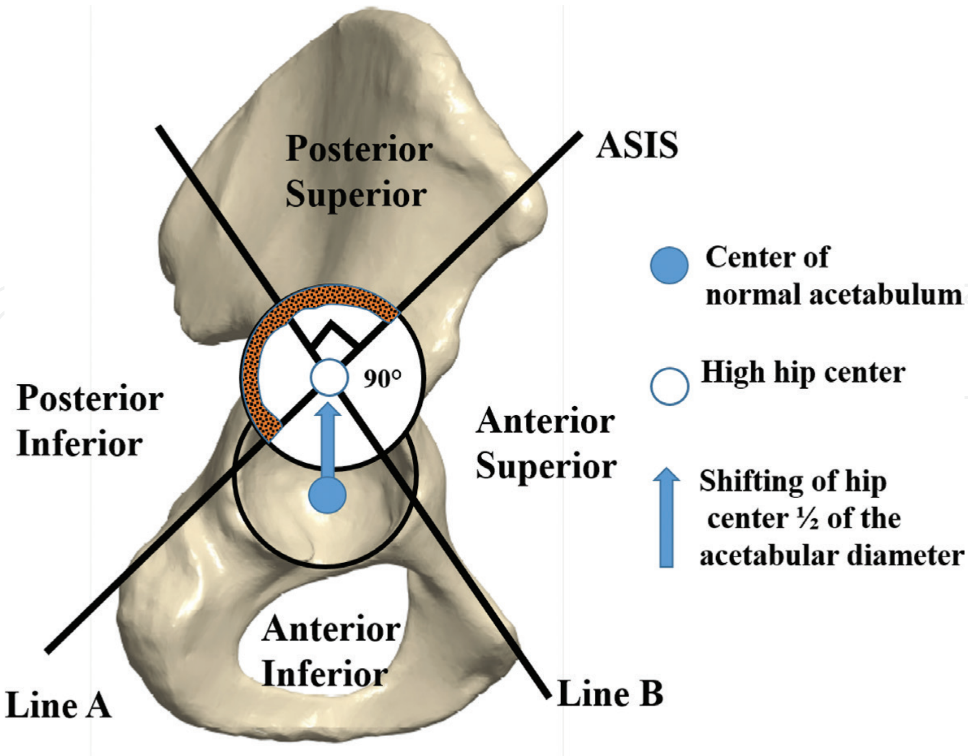

Figure 5. Illustration of screw placement zones in the high hip center.

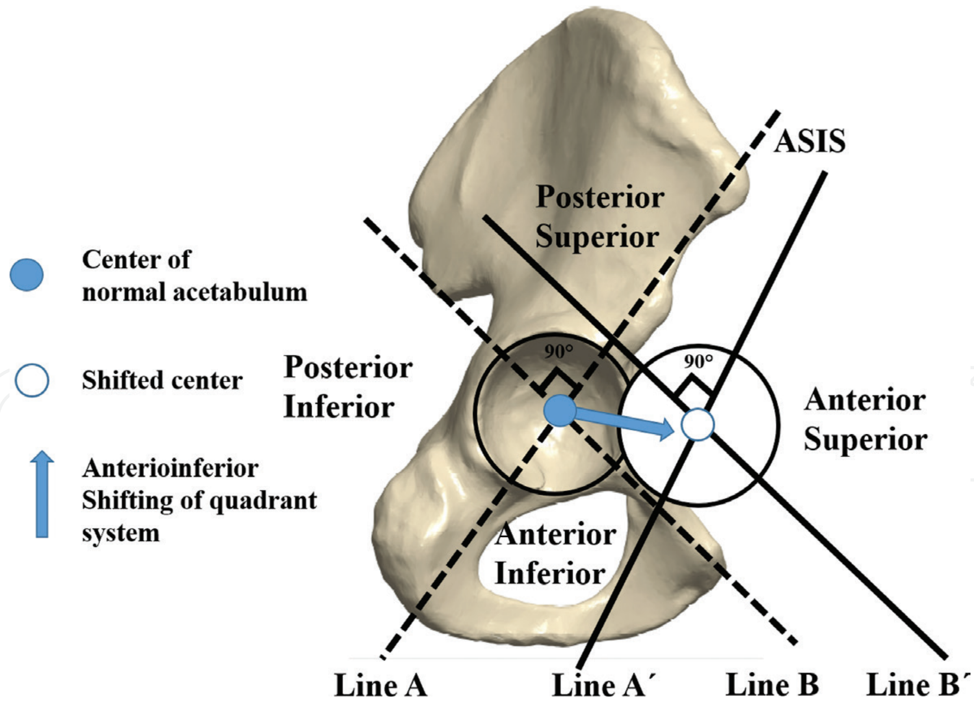

Figure 6. Illustration of shifted quadrant system anteroinferiorly in Crowe type-IV developmental dysplasia.

compression is critical to minimizing the vascular injury during total hip arthroplasty. Placing the anterior acetabular retractor at anterior inferior iliac spine and inferior acetabular retractor to the anterior wall is the safest position to avoid vascular injury during total hip arthroplasty.

2.4. Acetabular reinforcement ring and antiprotrusio cage

Acetabular reinforcement ring and antiprotrusio cages are generally used in traumatic hips and revision surgeries [35]. These prosthesis enable to fix the screws to actualize the pre-existing anatomical conditions of acetabulum. Avoiding the risk of vascular injuries, screw positioning in ventral and dorsal type of prosthesis is generally avoided. However, in such critical anatomical situations, radiological interventions must be required during surgery.

2.5. Cement

During cemented total hip replacement surgeries, cement must be allowed to reach lesser pelvis. Postoperative vascular complications occur due to cement extrusion in defect of acetabular wall can put external iliac vessels at risk. Excessive use of cement (methyl-methacrylate) can cause exothermic reaction, resulting in vessel thrombosis. Cement spiculae can erode through the artery and result in perforation and pseudoaneurysm formation in postoperative duration. The vessels are susceptible to avulsion if a revision surgery becomes necessary and intrapelvic cement is unwisely extracted.

3. Management

3.1. Preoperative management

3.1.1. Preoperative clinical investigation

The preoperative clinical examination of vessels must be carefully performed. Knowledge and local anatomy of vessel status surrounding the pelvis before surgery is essential and if necessary, surgeons must use the easier method like Doppler scan to measure the arterial occlusion pressure. Few arteries like femoral artery defects are easily identified in these examinations, while artery defects for the arteries like obturator and superior gluteal artery are often difficult to diagnose in early preoperative period.

3.1.2. Preventive measures

In case of revision total hip surgeries and traumatized hip, an appropriate vascular surgeon must be intimated prior to performing total hip replacement surgeries.

3.2. Intraoperative management

A high index of disbelief and careful intraoperative inspection are fundamental to immediate diagnosis and treatment of most intraoperative vessel injuries, both in primary and revision total hip surgeries. Sudden vascular injury at the time of surgery may be caused my many means for example instrumentation, broken bone edges, implants etc. Prompt recognition of vessel injury is important. In these injuries, the essential step is of course bleeding control.

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Surgeon must not underestimate the urgency of vessel injury even in slight signs of bleeding. There are many steps that must be followed in such types of situation, which are listed below

- In open massive bleeding or slight signs of bleeding, immediate bleeding sights must be identified visually, and operated to stop the hemorrhage. Additionally, ultrasonography is the easiest and immediate way to recognize the site of bleeding in closed or open cases.
- In acute hemorrhage at first site, surgeons must put pressure for local control at either end of injured vessels.
- Additional supplies of blood and fresh frozen plasma must be done.
- Coagulation and legation technique for smaller vessels can be useful for temporary control of bleeding.
- Compression technique if unsuccessful at first attempt must be followed by surgical legation, endovascular stenting, and bypass as the next step for sites of vessel injury.
- Without time delay, vascular surgeons must be intervened to take the operative actions and stop the bleeding immediately.
- The operating orthopedic surgeon must be familiar with the advanced operative techniques like ilioinguinal and Stoppa approach for intrapelvic exposure, generally used in major injured vessel repair.

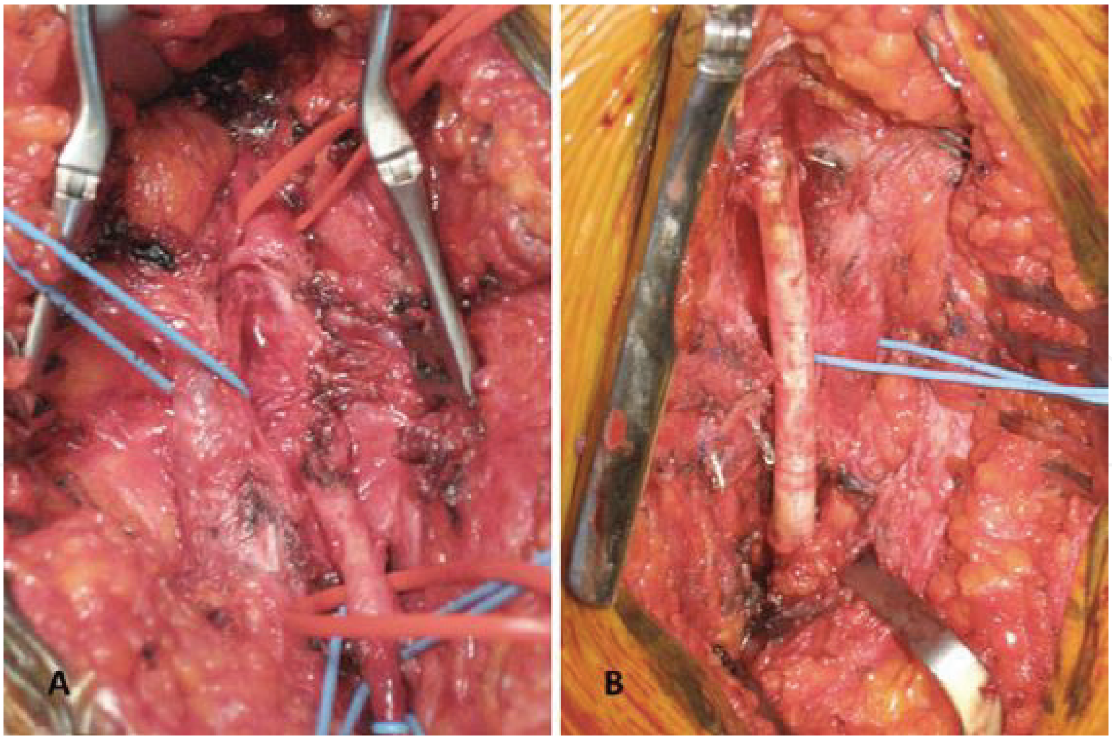

Figure 7. Photograph showing postoperative vessel injury. (A) Arterial injury between the distal external iliac artery and the femoral artery to the origin of deep femoral artery. (B) Arterial bypass (reprinted with permission from Barbier et al. [36]).

3.3. Postoperative management

Postoperative insult of vessel injury by surgeons, which is the slightly lesser common cause of unexplained pathological complications, might even result in death. Immediate after surgery to few days of recovery, careful monitoring of vessel status is essential to avoid postoperative vessel complications. After surgery and in the late postoperative period there are many sign and symptoms, the surgeons, and even individual must not circumvent, of course, it may be the sign of late vascular injury. Unexplained hypotension, tachycardia, nerve palsy, hypovolemic shock and decreased hemoglobin and blood pressure are the signs of vascular injury, postoperatively. In postoperative cases with the above signs and symptoms, immediate axial imaging or radiography, contrast-angiography, color ultrasonography are the more natural way to diagnose the bleeding source. Monitoring of these signs wisely is better and can be treated with open repair, stenting, bypass, coiling, or chemoembolization without any delay (**Figure 7**) [37–39]. The late symptoms from false aneurysm formation might be in the broad range of spectrum and very confusing and can be treated by surgical intervention, once the vascular injury is determined by diagnosis [13, 19].

Total hip replacement surgery is largely performed in aged patients and possibility of arteriosclerosis vessel must be taken into account, as these vessels are more vulnerable to injury [29].

4. Conclusion

Conclusively, vascular injuries are rare in hip replacement surgeries. Careful preoperative planning, better instrumentation, knowledge of anatomical structures and meticulous surgical technique are necessary to avoid vascular injury. In advent screw penetration leading to vascular injuries can present early as hemorrhage during surgery, in the intermediate term as postoperative bleeding, hypotension, etc., and late as pseudoaneurysms. Further, management of these complications is beyond the scope of this chapter which focuses on prevention of these injuries rather than its management.

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Conflict of interest

The authors declare no conflict of interest.

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