ISSN 2563-7142

MINI REVIEW

Vascular Anatomy of the Proximal Femur and the Risk of Avascular Osteonecrosis

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Hegazy AA, Hegazy MA. Vascular Anatomy of the Proximal Femur and the Risk of Avascular Osteonecrosis. Int J Cadaver Stud Ant Var. 2025;6(1):10-14.

Abstract

The high complication rate associated with femoral neck (FN) fracture, particularly the development of avascular necrosis (AVN) of the femoral head (FH), may be explained by the vascular anatomy of the proximal femur. The FH AVN is a devastating disease and greatly affects the quality of life. Therefore, clarifying the arterial blood supply to the FH is the aim of this short review. Despite the rich blood supply to the FH, it is one of the most susceptible bone structures to AVN. It is supplied from two main blood sources: the femoral artery through the medial and lateral circumflex femoral arteries, and the internal iliac artery through the superior and inferior gluteal arteries, as well as the obturator artery. The main blood supply vessels pass through the retinacular capsule of the hip joint along the relatively long FN. Displaced fragments after a FN fracture can tear these blood vessels, affecting the blood supply to the FH. Early management of such cases may reduce the risk of developing AVN. Future studies are highly recommended to further explore the main source of blood supply to the FH especially at different ages. Clarification of such arrangement can help explain the risk of development of FH AVN and allow safe surgical exposure of such region.

Key Words: *Anatomy; Femoral head; Femoral neck; Avascular necrosis; Orthopedics*

The femoral head (FH), the proximal part of the femur, is spherically shaped with a medial depression called the fovea capitis attached to the ligamentum teres. The FH is supplied with blood by numerous arteries, yet it is one of the bone structures most susceptible to the development of avascular necrosis (AVN). Approximately 10,000 to 20,000 new cases of FNAVN are reported annually in the United States alone [1]. The FH articulates with the acetabulum of the hip bone to form the hip joint (Figure 1), which is one of the most mobile joints in the human body. This, along with other factors such as its angled connection to the femoral shaft (FS) via a relatively long neck, can play a role in disrupting the blood supply in cases

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Received: March 21, 2025, Accepted: April 14, 2025, Published: April 23, 2025

of femoral neck (FN) fracture or hip dislocation [2]. Fractures of the FN can be classified as traumatic fracture, (such as a traffic accident or a fall from a height), or pathological fracture, especially in the elderly, which can occur after a low-energy shock or excessive activity [3]. Other researchers have added hormonal disorders as risk factors for AVN of the FH [4]. This includes prolonged use of glucocorticoids, which may disrupt microcirculation in the bones, leading to fractures of the cancellous bone tissue of the FH [5,6]. Furthermore, surgical repair of FN fracture in children may be complicated by the disruption of bone growth [3]. Other complications of surgical repair can include infection, nonunion, premature physeal closure, difference in length of the lower extremities, and coxa vara [7]. Knowledge of the anatomy of different parts of the human body and their associations with clinical practice can aid in surgical repair and reduce or eliminate potential complications [8,9]. The complications associated with FN fracture can be explained by the vascular anatomy of the proximal femur [10]. Clarification of such distribution can explain the development of AVN of the FH and allow safe surgical exposure of such region [11]. There are various descriptions of the blood supply to the FH in the literature. Therefore, elucidating the distribution and arrangement of the arterial blood vessels supplying FH that may help explain the risk of development of FH AVN is the aim of this short article.

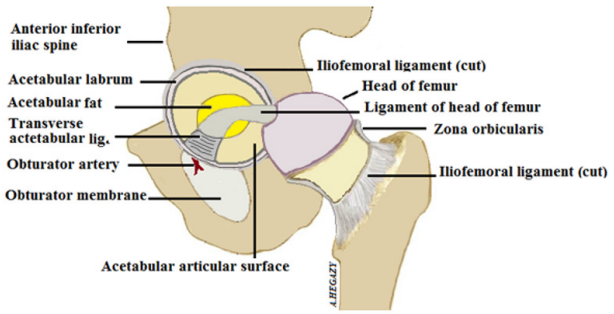

Figure 1) *Diagram of hip joint (opened) showing the articular structures.*

The FN is considered a fragile bone area that is prone to osteoporosis and thus fractures in adults. The FN is a truncated cone in the shape of a trapezoid with two ends: the upper narrow end which supports the head, and the lower broad end connecting it to the FS. It is directed upwards and medially forming an obtuse angle with the FS [12]. This obtuse angle is largest at birth but decreases and becomes less obtuse with age until adulthood. The angle in young children is about 160° while it is about 125° in adults. An increase in the angle with deviation of the FS laterally is called coxa valga and occurs, for example, in a hip joint with developmental dysplasia [13]. At the same time, a decreased angle with internal deviation of the FS is known as coxa vara (Figure 2). In the case of coxa vara, there is a slight shortening of the affected lower limb [13]. Post-traumatic coxa vara can occur in children as a result of screw fixation of the FN [14]. Moreover, trauma can affect the physis or growth plate by reducing its blood supply and thus lead to shortening of the limb [13].

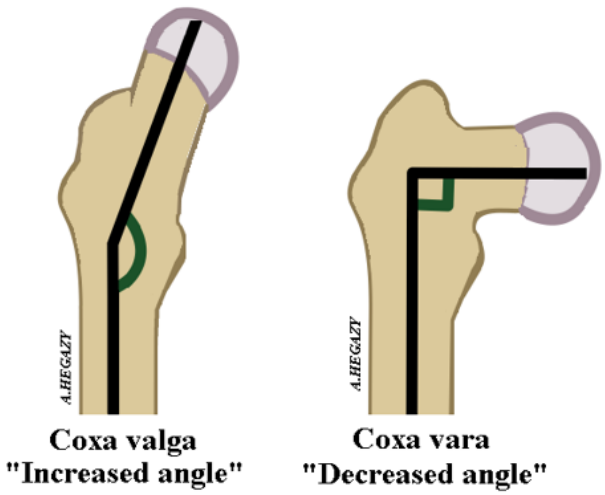

Figure 2) *Diagrams showing inclination angle between the long axes of the shaft and neck of femur.*

FH AVN is a devastating disease and greatly affects the quality of life. This often results in significant disability and suffering for the patient. Although surgical interventions such as total hip replacement have improved quality of life, this

is not without consequences, including limited implant life and potential complications [4].

The distribution and arrangement of blood supply to the FH could explain the possibility of AVN occurring when the FN is fractured [12]. The main blood supply to the FH comes from the medial and lateral circumflex femoral arteries (MCFA and LCFA) that arise from profunda femoris artery (PFA), which originates from the femoral artery (FA). MCFA and LCFA form an anastomotic extracapsular arterial ring at the root of the FN from which the retinacular branches pass to the FH [17]. In addition to retinacular branches, the head of femur receives another two sources of blood supply. The first is a branch from obturator artery (OA) travelling along the ligament of the FH; however, it is not capable of keeping the head alive if other sources are lost [1]. In most of the population (about two-thirds), the OA arises from the anterior division of the internal iliac artery (IIA). In a small percentage (about one-third), its origin is variable; it may arise from the inferior epigastric artery, followed by the external iliac artery (EIA), and, less commonly, from the iliolumbar artery [18]. The last source are twigs arising from the nutrient arteries of the FS (Figure 3). Poor blood supply to the FH in children may be due to presence of the cartilaginous epiphyseal plate that can separate blood flow in the bony FS from anastomosing with that of the FH [1]. The FS nutrient arteries are one or two arteries that arise from the PFA and popliteal arteries. These arteries enter the bone through the nutrient foramina, located along the linea aspera [19]. Interestingly, the artery of ligamentum teres, which is of great importance in children in supplying the FH, can be damaged by hip dislocation [1,2]. Some authors have proposed a contribution to the blood supply of the FH by the cruciate anastomosis, which forms a connection between the FA and IIA [11]. The cruciate anastomosis is located at the level of lesser trochanter of the femur. The arteries involved in such communications include, in addition to the transverse branches of the MCFA and LCFA, the descending branch of the inferior gluteal artery (IGA) as well as the ascending branch of the first perforating artery [13]. Grose et al. added that there is a clear anastomosis between the IGA and the MCFA before the latter artery passes deep to the hip joint capsule [11]. However, the trochanteric anastomosis, which is located near the trochanteric fossa and consists of the MCFA and LCFA with the superior gluteal artery (SGA) and IGA, is the main blood supply to the FH (Figure 4) [13,15]. It can be concluded that both iliac arteries, the IIA and EIA, share the blood supply to FH. The SGA and IGA, as well as the OA, are branches of the IIA, while the MCFA and LCFA as well as the first perforating artery arise from the PFA of FA which is the continuation of EIA in the thigh [13].

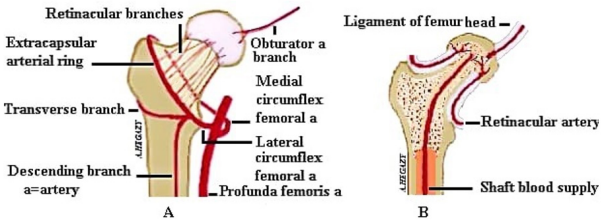

Figure 3) *Diagrams showing blood supply of femur head: A) External aspect; B) Coronal section.*

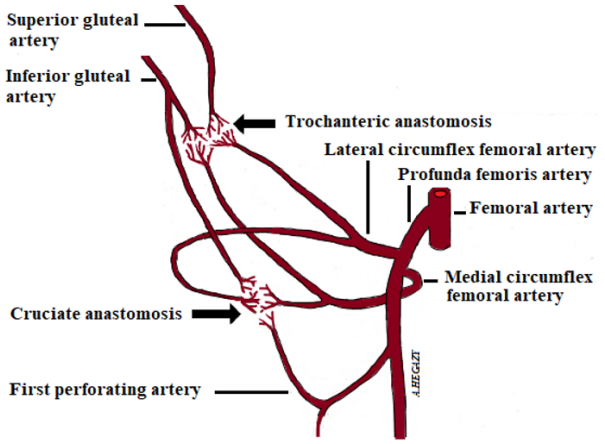

Figure 4) *Diagram showing arteries forming the trochanteric and cruciate anastomoses at the upper end of femur.*

Pediatric fractures of the FN (PFNF) are classified according to Delbet classification into four types [16-20]. The first type of fractures is transepiphyseal; the second type is transcervical and the type III fracture site is basicervical or cervicotrochanteric, while the type IV fracture site passes between the two trochanters. The most common of the four types is type 2 "transcervical fracture" [16]. The first three types include the hip capsule while the 4th type is extracapsular [21]. Therefore, only the last type "intertrochanteric fracture" would escape the AVN due to the unaffected retinacular blood supply.

The most common complication of open surgical reduction of FN fractures is AVN, which may occur due to disruption of FN blood supply to the FH [22,23]. The incidence of AVN is lower in non-displaced PFNF than in displaced fractures and when treated early after the fracture [24]. Displaced fractured bone fragments can affect the ascending branches that pass along the FN and thus may obstruct the blood supply leading to non-union or AVN of the FH. Due to the arrangement of the blood vessels that supply the FH, it is important to reduce a FN fracture as quickly as possible to avoid any complications, including AVN, that may arise [3]. This is especially important for children because the lesion is located near or involves the physis or growth plate through which bone growth can occur.

Conclusion

Although the FH is supplied with blood through numerous blood vessels, it is susceptible to development of AVN caused by many factors, especially FN fracture. It is supplied by two main blood sources: the FA, which is the continuation of EIA in the thigh, through the MCFA and LCFA, and the IIA through the SGA and IGA, as well as the OA. The main blood supply vessels arises from the trochanteric anastomosis, and pass through the retinacular capsule of the hip joint along the relatively long FN. Displaced fragments after a FN fracture can tear these blood vessels, affecting the blood supply to the FH. Early management of such cases may reduce the risk of developing AVN. Future studies are highly recommended to further explore the blood supply to the FH and investigate how to prevent the occurrence of AVN and disease progression.

Acknowledgment: All figures included in the paper are original and created by the first author.

List of Abbreviations:

AVN: Avascular Necrosis

EIA: External Iliac Artery

FA: Femoral Artery

FH AVN: Femoral Head Avascular Necrosis

FH: Femoral Head

FN: Femoral Neck

FS: Femoral Shaft

IGA: Inferior Gluteal Artery

IIA: Internal Iliac Artery

LCFA: Lateral Circumflex Femoral Artery

MCFA: Medial Circumflex Femoral Artery

OA: Obturator Artery

PFA: Profunda Femoris Artery

PFNF: Pediatric Fracture of the Femoral Neck

SGA: Superior Gluteal Artery

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