Original research article

A Study of Nutrient and Vascular Foramina of Dry Adult Human Femur

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Abstract

Background: Femur is richly vascularized bone deriving its arterial input from umpteen vessels. The lower end is generously supplied by the genicular arteries and is seldom more frequently subjected to ischaemic necrotic attacks. The upper end of the femurin general showed rich vascularization with the exception of the lesser trochanter.

Methodology: The present study was undertaken on 100 dry adult normal human femur bones of both sides, irrespective of sex. The bones were obtained from the Department of Anatomy, PMCH, Patna Study duration of Three years.

Conclusion: In the present study, blood supply was found to be maximum at the lower end followed by upper end and the shaft respectively, suggesting the lack of ischaemic necrosis after fractures of the lower end. Medial lip of linea aspera depicted the presence of nutrient foramina in majority of bones suggesting the entry zone for nourishment of shaft by perforating arteries.

Keywords: Vascular Foramina, Nutrient Foramina; Ischaemic Necrosis; Perforatingarteries; Lesser Trochanter; Greater Trochanter.

Introduction

The femur is the long bone of the thigh. It shows wide range of modifications in its architecture. Femur is the bone which is susceptible to the functional hormonal disturbances, aging process and physical traumas which account for its usual fractures and dislocations. The bone is a highly vascular structure with unique features in its blood supply[1]. A typical long bone is fed by four groups of arterial systems, which are -a nutrient artery, epiphyseal, diaphyseal and periosteal arteries[2].The femur being a long bone receives nutrition via the above said arteries. The arteries supplying this long bone pervade into it via numerousforamina located over its different segments, being named as vascular foramina. Among these vascular foramina, nutrient foramen is an important one which gives way to the nutrient artery. The nutrient arteries of the femur usually arose from the perforating branches of the profunda femori artery, less commonly direct from the profunda femori and rarely from the lower segment of the femoral artery. The course of the nutrient arteries will be constant, the arteries run under the adductor magnus muscle, and through the nutrient foramina which lay on or near the lineaaspera of the femur. The nutrient foramina of the femur are usually situated on the posterior surface, near the linea aspera of the femur[3]. Knowledge of vascular anatomy is helpful in early identification of vascular interruptions leading to osteonecrosis. Through the periosteal and nutrientvessels, the major part of a long bone receives its blood supply from numerous points all along its length, therefore fracture cannot deprive either part of all itsblood supply. The vascular anatomy of femur is of utmost importance because it is relevant to fracture treatment. Combined periosteal and medullary blood supply to the bone cortex helps to explain the success of intramedullary reaming of long bone fractures particularly in the weight bearing femur[4].

Three groups of vessels supply the upper end of femur, namely nutrient artery of the shaft, the retinacular or capsular arteries and the foveolar artery or arteryof ligamentum teres. Avascular necrosis of the femoral head is most often seenafter fracture of the neck of the femur but it may also be due to slipping of the upper femoral epiphysis, reduction of congenital dislocation of hip joint and pyogenic or tuberculous infections of the femoral neck, it is the pathological basis of perthe's disease[5]. The shaft is supplied by the vessels from perforators of the thigh which gives nutrient branches to it. The blood supply acts as a most vital factor to deal with problems like malunion, osteomyelitis and other conditions affecting the diaphysis[6]. The distal end of the femur has generous blood supply by branches of popliteal artery. It is so abundant that it seems unlikely for any fracture here could cause necrosis[7]. Most vascular foramina are located close to the antero- and posterosuperior regions of the femoral head and neck junction. This larger segment should be carefully protected during any conservative intracapsular procedure of the hip and may be desirable in femoral head resurfacing arthroplasty[8]. For the transplantation of allogenic vascularized femoral diaphysis, the deep femoral artery can be used if the lateral femoral circumflex artery is protected. For shorter grafts one must consider the number and location of nutrientforamina. For longer grafts the distal branches of the femoral artery must be respected[9]. According to Crock, the apparent age related variations in arterial appearance at head and neck represent in part, changes in position of epiphyseal plate, enlargement of secondary center and increase in surface area supplied by samenumber of arteries[10]. Bridgemann and Brookes suggested that with increasing age the medullary blood supply becomes important for survival of bone cortex in old age[11]. Based on this hypothesis, it is worth to find whether the number and size of vascular foramina including the nutrient foramina also keep changing.

Objectives

To observe the location or distribution of vascular foramina in differentsegments of femur. To quantify the number/density of the foramina. To measure the size of the foramina.

Review of Literature

The femur is the longest and strongest bone in the human body. Its shaft, almost cylindrical in most of its length and bowed forward, has a proximal round, articular head projecting mainly medially on its short neck, which is a medial curvature ofthe proximal shaft. The distal extremity is more massive and is a double 'knuckle' (condyle) that articulates with the tibia. Proximally the femur consists of a head, neck, and greater and lesser trochanters. A potentially significant difference exists between the intraosseous and extraosseous blood supply to the medial and lateral femoral condyles that may explainthe higher frequency of ischemic events occurring in the medial femoral condyle. The close proximity of the extraosseous vessels to the medial femoral condyle and the standard femoral tunnel used during posterior cruciate ligament reconstruction may explain the occurence of avascular necrosis after this procedure[12]. extracapsular anatomy of the MFCA and its surrounding structures will help to avoid iatrogenic avascular necrosis of the head of the femur in reconstructive surgery of the hip and fixation of acetabular fractures through the posterior approach[13]. In the fibula the nutrient foramen was found in the 68% in the posterior surface;14% in the medial surface; 12% in the interosseous border; 4% in the lateral surface and 2% in the posterior border. This data was used as reference for surgical procedures of the lower limb[14]. The majority of the bones studied had a single nutrient foramen, which may represent a single source of blood supply. This data was used for comparison and in surgical procedures and in the interpretation of radiological images[15].

Material and methods

The present study was undertaken on 100 dry adult normal human femur bones of both sides, irrespective of sex. The bones were obtained from the Department of Anatomy, Patna medical college and Hospital Patna, Bihar. Study duration of Three years. Dry adult human femur bones of both sides, irrespective of sex were included.

Deformed, damaged bones, bones with callous formation and unossified boneswere excluded from the study.

The materials used to calculate the parameters in this study are as follows:

1) Cotton swab
2) Formalin solution
3) Marker pens

18, 20, 22, 24 gauge hypodermic needles

Material used

The dry adult human femur bones were cleaned properly with cotton swabdipped in formalin solution. These bones were numbered using the marker pen from 1 to 100 numbers in order The hypodermic gauge needles were cleaned with cotton swab dipped in formalin solution. The gauge needle number 18 was put in each of the vascular foramina in the different segments of the femur and the number of vascular foramina accommodating 18 gauge needle were counted and their total number was tabulated in the data sheet.

Similarly, the hypodermic gauge needle numbers 20, 22, 24 were put in eachof the vascular foramina in the different segments of the femur bone and the numberof vascular foramina accommodating 20, 22, 24 hypodermic gauge needles were counted and their number was tabulated in the data sheet respectively.

a) horizontal direction.

NUTRIENT FORAMINA

The hypodermic gauge needles were cleaned with cotton swab dipped informalin solution. The hypodermic gauge needle was put into the foramina and the number ofnutrient foramina were counted and tabulated in the data sheet.

The location of nutrient foramina on the femur bone was noted and wastabulated on the data sheet.

To locate the nutrient foramina, the femur bone was divided into differentsegments:

Based on the hypodermic gauge needle number which was admitted by the nutrient foramina, the foramina were categorized into 4 groups.

a) Large sized nutrient foramina: - The foramina which admitted 18 gauge needle were considered to be between i.e., 1.27 mm or more [≥ 1.27 mm].
b) Medium sized nutrient foramina: - The foramina which admitted 20 gauge needle were considered to be between 0.90 mm and 1.27 mm [≥ 0.90 to < 1.27mm].
c) Small sized nutrient foramina: - The foramina which admitted 22 gauge needle were considered to be between 0.71 mm and 0.90 mm [≥ 0.71 to < 0.90 mm].
d) Very small sized nutrient foramina: - The nutrient foramina which admitted 24gauge needle were considered to be between 0.55 mm and 0.71mm [≥ 0.55 to < 0.71 mm].

Results

Table 1: Number of Nutrient foramina in various segments

Number of NutrientForamina	Total Number of Femora	Percentage
0	0	0
1	62	62
2	37	37
3	1	1
Total	100	100

Table 2: Location of nutrient foramina in various segments

Location [A]	Number ofNutrient Foramina	Percentage
Medial lip of line aspera	87	62.6
Lateral lip of linea aspera	26	18.7
Medial Surface	14	10.1
Upper posterior surface	12	8.6
Total	139	100

Table 3: Direction of nutrient foramina in different segments of femur

Direction	Number of Nutrient Foramina	Percentage
Upper	139	100.0
Lower	0	0.0
Horizontal	0	0.0
Total	139	100

Table 4: Average number of vascular foramina in different segments of femur

Segments of femur	Minimum	Maximum	Mean	Standard deviation

Upper End	41	167	63.0	13.5
Shaft	2	7	3.8	0.9
Lower End	100	145	117.9	7.4

Table 5: Average number of vascular foramina of different sizes in differentsegments of femur

Segments of femur	>= 1.27 mm	>= 0.90 to <1.27 mm	>= 0.71 to <0.90 mm	>= 0.55 to <0.71 mm
Upper End	0.46	0.61	0.94	5.76
Shaft	0	0	0	0.54
Lower End	0.75	1.40	2.10	19.30

Table 6: Average direction of vascular foramina of different sizes in differentsegments of femur

Segments of femur	Upper	Lower	Horizontal
Upper End	0.71	1.23	5.79
Shaft	0.20	0.04	0.31
Lower End	0.75	1.10	21.69

Among 100 femora studied, 62 femora had single nutrient foramen, 37 had twonutrient foramina and 1 had three nutrient foramina.
i.e., 62 % bones had one nutrient foramen37% bones had two nutrient foramina1% bones had three nutrient foramina.

87 nutrient foramina were present on medial lip of linea aspera. i.e., 62.6%26 nutrient foramina were present on lateral lip of linea aspera. i.e., 18.7% 14 nutrient foramina were present on medial surface. i.e., 10.1%12 nutrient foramina were present on upper posterior surface. i.e., 8.6% In the lower end, the average number of vascular foramina directed horizontally was about 21.69, those directed in upper direction was about 0.75, and those directed in lower direction was about 1.10. Out of three segments of the femur, maximum average number of vascular foramina directed horizontally was observed in lower end and minimum average number was observed in shaft. Maximum average number of vascular foramina directed in upper direction wasobserved in lower end and minimum in shaft.

VF in greater trochanter

Maximum average number of vascular foramina directed in lower direction wasobserved in upper end and minimum in shaft.

VF on anterior surface of neck

VF on medial surface of medial condyle

Discussion

Femur is the most richly vascularized long bone which derives its nourishment from various arteries of the lower limb. Chief arteries which supply it are femoral artery, obturator artery, profunda femoris artery, popliteal artery, perforating arteries and quantum of blood supply by each is determined by the number and calibre of these arteries based on differences in the arterial inputs, the bone exhibits differentialischemic attacks. Generous vascular supply of popliteal artery explains the lack of ischemic necrosis of lower and in contrast to frequent ischemic necrotic attack of upper end of femur nourished by many arteries. The neck region at the upper end of the femur bone is per se showed maximum number of vascular foramina of which speaks for enormity of vascularity inquantitative terms. This is due to abundance of extra osseous and intraosseous anastomosis among various groups of neck arteries. These arteries show established links above with arteries and below with diaphyseal arteries. The greater trochanter followed in next order for rich vascularity greatertrochanter is a traction epiphysis with insertion of muscles around it and therefore derives its blood supply from the extra osseous vessels. Churchill[16] suggested that greater trochanter has a separate blood supply even after bony fusion with the shaft and these are few anastomoses with adjacent diaphyseal vessels. The above mentioned information may prove very useful in surgical detachment of greater trochanter in hip surgery and its healing process. Lesser trochanter was the site in the upper end with least vascularity and probably the source of supply to it is from first perforating artery. Whether thisfeature could be attributed to the possibility of avascular plane due to failure of anastomosis between it and its neighbouring arteries is worth postulating. Moreover the existence of the lesser trochanter at the neck shaft angle where weight is transmitted from the neck to the shaft could be a causative factor for the delay in the healing process is worth thinking. The shaft of the femur is adapted to the lines of stress and weight transmission. As a structural adaptation to it, thickening of the medullary wall and the appearance of linea aspera could be appreciated. The blood supply to medullary wall of the shaft is disputed. Trias and Ferry[17] stated that cortices of long bones are dependant for their nourishment from vessels of periosteal and medullary circulatory system, the latter is mainly derived from branches of nutrient artery. He also suggested that periosteal vessels supply outer one third to one fourth of the cortex while medullary arteries supply inner two third to three fourth of the cortex. The most highlighting observation made about nutrient foramina is pertaining to their location at the junction of upper one third and middle one third of the shaft. This area is prone for subtrochanteric fractures which may lead to alarming haemorrhage thus highlighting its applied significance. One more pecularity of the location of nutrient foramina is that majority of nutrient foramina [65.6%] were located at the medial lip of linea aspera which shows that the entry of nutrient artery was close to medial lip of linea aspera. This suggests that the medial lip of linea aspera is the entry zone for the vascularity to the shaft.This definitely gains significance from surgical point of view as surgical interference in this region should be done with utmost care. In the present study, the vascularity to the lower end of femur was found to be very rich as indicated by higher density of vascular foramina. Lower end shows maximum number of vascular foramina of all sizes, in particular the medial condyle showed highest density. The present findings are in full agreement to the previous investigations conducted by and Rogers[7]. The abundance of blood supply to distal endof femur in contrast to proximal end relates to fracture and other traumatic injuriesand their frequencies. Most convincingly this is rationale behind the non-occurrenceof ischaemic necrosis following fractures in the distal end. The higher degree of vascularity to medial condyle in per se is perhaps due to generous arterial supply by three genicular arteries unlike two on the lateral side as well as their anastomoses withneighbouring vessels.

Conclusion

The present study conducted on nutrient and vascular foramina of 100 dry adulthuman femora arrived at a conclusion that the different segments of femur have differences in the intensities of blood flow to them, as revealed by densities ofvascular foramina. The lower end of femur is highly vascularized as indicated by high density of vascular foramina in this area. The upper end of the femur in general showed rich vascularization with the exception of the lesser trochanter which is very close to the neck shaft angle. The shiftof the weight transmission occurs from neck to the shaft approximately at the site of lesser trochanter. Whether the low vascularity at this region has anything to do with healing is worth considering.

References

1. Laroche M. Intraosseous circulation from physiology to disease. Joint Bone Spine. 2002;69: 262-69.
2. Datta AK. Principles of general Anatomy.6th ed. Kolkata, India : Current books international; 2010.p.75-77.
3. Qin Yueqin, Cheng Xinheng, Wu Jinbao, Bai Huiying. The diaphyseal nutrient foramina and the nutrient arteries of the femur in chinese. Acta Anatomica Sinica. 1984-03.
4. Al-Motabagani, M A H. The Arterial Architecture Of the Human Femoral Diaphysis. J Anat. Soc. India. 2002; 51(1):27-31.
5. Tucker FR. Arterial supply at the femoral head and its clinical importance. J Bone Joint Surg Br. 1949 Feb;31B(1):82-93. .
6. Robert WJ. A physiological study of the blood supply of the diaphysis. Jour Bone And Joint Surg. 1927:153-184.
7. Rogers WM, Gladstone H. Vascular foramina and arterial supply of the distal end of the femur. J Bone Joint Surg Am. 1950 Oct;32(A:4):867-74.

8. Lavigne M, Kalhor M, Beck M, Ganz R, Leunig M. Distribution of vascular foramina around the femoral head and neck junction: relevance for conservative intracapsular procedures of the hip. Orthop Clin North Am. 2005 Apr;36(2):171- 6.
9. Kirschner MH, Menck J, Hennerbichler A, Gaber O, Hofmann GO. Importance of arterial blood supply to the femur and tibia for transplantation of vascularized femoral diaphyses and knee joints. World J Surg. 1998 Aug;22(8):845-51.
10. Crock HV. A revision of the anatomy of the arteries supplying the upper end of the human femur. J Anat. 1965 January; 99(1): 77–88.
11. Bridgeman G and Brookes M. Blood supply to the human femoral diaphysis in youth and senescence. J Anat. 1996 June; 188(3): 611–621.
12. Reddy AS, Frederick RW. Evaluation of the intraosseous and extraosseous blood supply to the distal femoral condyles. Am J Sports Med. 1998 May- Jun;26(3):415-9.
13. Gautier E, Ganz K, Krügel N, Gill T, Ganz R. Anatomy of the medial femoral circumflex artery and its surgical implications. J Bone Joint Surg Br. 2000 Jul;82(5):679-83.
14. Erika Collipal, Ramiro Vargas, Ximena Parra, Héctor Silva, Mariano del Sol.
15. Diaphyseal Nutrient Foramina in the Femur, Tibia and Fibula Bones. Int J. MorphoL. 2007;25(2):305-308.
16. Pereira G A M, Lopes P T C, Santos A M P V& Silveira F H S. Nutrient foramina in the upper and lower limb long bones: Morphometric study in bones of Southern Brazilian adults. Int. J. Morphol.2011;29(2):514-520.
17. Churchill MA, Brookes M, Spencer JD. The blood supply of the greater trochanter. J Bone Joint Surg Br. 1992 Mar;74(2):272-4.
18. Freeman MA. Some anatomical and mechanical considerations relevant to the surface replacement of the femoral head. Clin Orthop Relat Res. 1978 Jul- Aug;134:19-24.