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Research Article

TOPOGRAPHY OF NUTRIENT FORAMINA OF ADULT DRY RADII IN SOUTH INDIAN POPULATION WITH A NOTE ON ITS SURGICAL RELEVANCE

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ABSTRACT

Objective: The objective of this study was to study the average length of adult dry radii in south Indian population, distribution of nutrient foramina, and foraminal index.

Methods: This study was conducted using 200 dry, adult radii, obtained from the department of Anatomy at our institute. Fully formed radii of both sides and genders were included in the study. Length of each bone, distribution, and direction of nutrient foramina on diaphysis were studied with the help of a Vernier caliper. Later, foramen index was estimated for all bones using Hughes formula. The data were tabulated and analyzed statistically.

Results: Average length of radii in the study was 23.37±1.65 cm. All radii had their nutrient foramina, directed proximally. About 2% of the study sample had double nutrient foramina. Increased number of foramina had no effect on length of bone. As many as, 57.5% of radii had nutrient foramen on the anterior surface of shaft. Mean foramen index was 34.24±4.75.

Conclusion: This study provides population-specific data regarding length of adult radii and topography of nutrient foramina of adult radii. An attempt was made to acknowledge its relevance while harvesting a vascular graft.

Keywords: Radii, Nutrient foramina, Foraminal index, Surgical relevance of nutrient foramina.

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INTRODUCTION

Unlike cartilage, bone is a vascularized connective tissue. Blood vessels orchestrate the process of ossification, growth, remodeling, and regeneration of bone by delivering nutrients, oxygen, growth factors, or hormones to the bone cells. As much as, 5.5–11% of cardiac output is received by skeletal vasculature [1]. Besides, vascularity of bone has got a key role in healing [2]. Vascular invasion of cartilaginous callus is important in bone healing and its disruption can cause delayed union or non-union in up to 50% cases [3,4]. Moreover, study by Grosso *et al*. [5] emphasized the importance of blood supply in bone grafting by concluding that bone graft consolidation/repair is a complex biological process regulated by the angiogenesis and osteogenesis coupling phenomenon.

A long bone derives its blood supply from periosteal vessels and nutrient artery and the latter is considered to be the principal source [6]. Vessels which invaded the ossifying cartilage develop into nutrient arteries [7]. Nutrient artery enters the bone, horizontally or at right angle to the bone's long axis, through nutrient foramen (NF). NF leads to nutrient canal, carrying nutrient artery toward medullary cavity [8]. Soon, NF becomes obliquely oriented and directed toward the non-growing end of the bone due to difference in growth at both the ends [9]. If a surgeon is unaware of usual distribution of these nutrient foramina and damage an artery, it can lead to compromised outcome due to the obvious role of vascularity in healing [2-5]. This study was taken up with an aim to study the distribution of nutrient foramina on adult radii of South Indian population. Foraminal indices were also estimated.

METHODS

The present study was an observational type of study, conducted in the department of Anatomy. Study sample included 200 normal, dry, and adult radii. They were obtained from Osteology section of Anatomy department. Fully formed adult radii of both sides and gender were included in the study. Bones with gross pathology, distortion, fragmentation, and incomplete ossification were excluded from the study. Side determination of bones was done. Total length of each bone was measured using a Vernier caliper with accuracy up to 0.01 mm. Length was taken as distance from upper margin of head of radius to the tip its styloid process (Fig. 1). Bones were examined with unaided eye to look for presence of NF for location, direction, number, and distribution of NF over the shaft of bones. Once located, NF was confirmed by identifying a groove leading to it, forming a canal. When in doubt, a needle was passed through this canal to confirm its patency. If a foramen was found to be <1 mm away from a border, it is considered to be located on that border (Fig. 2). Distance of NF from proximal end of each bone was measured using Vernier caliper. When more than one foramina were noted, the bigger one was considered to take measurements. Further, the recorded measurements were used to calculate foraminal index (FI) using Hughes formula, that is, $FI=D/L\times100$ (D=Distance of NF from the proximal end of the bone, L=Total length of the bone). Range of distance of NF from proximal end of all bones was noted. Data was tabulated and analyzed using descriptive statistics such as mean, range, and standard deviation. Correlation coefficient (r value) was calculated to assess statistical correlation between length and duplication of NF. Statistical analysis was done using the Statistical Package for the Social Sciences, version 24.0.

RESULTS

Out of all 200 bones, 94 were of the right side and 106 were of the left side. About 99% (198) of bones had single NF except for two bones which had double nutrient foramina. NF of all bones was directed to the upper end of bone without any exceptions. Mean length of bones, irrespective of side, was 23.37±1.65 cm. No correlation was found between length of the bone and duplication of NF (*r=0.031*). Mean distance of NF from proximal end of bone was 8.17 cm on bones of the right side and 8.71 cm on bones of the left side. Mean FI of bones, irrespective of sides, was 34.24±4.75. Average length of bones, Mean FI, and range of distance of NF from proximal end and distal end of bone are shown in Table 1.

All bones were categorized into three types, based on their FI. Bones with FI <33.33%, 33.34%–6.66%, and more than 66.67% were placed in Type I, II, and III, respectively. Table 2 shows the distribution of bones into various types. None of the bones were found to be of Type III.

Fig. 1: Measuring total length of bone with Vernier caliper

Fig. 2: NF on anterior surface and interosseous border of radius

Table 3 shows topographical distribution of NF in relation to borders and surfaces of shaft, irrespective of side of the bone. Most frequently, they were found on anterior surface (57.5%) followed by interosseous border (20.5%).

DISCUSSION

Vascularity is vital for the process of bone formation, growth, and remodeling. Bone develops by two distinct processes: Intramembranous and endochondral ossification [8]. Endochondral ossification is prominent in the bones of the appendicular and axial skeleton, and the base of the skull. Fundamental to this process is the destruction of cartilaginous tissue derived from the primitive mesenchyme and its subsequent replacement with bone. Vascular invasion is an important phenomenon to convey osteogenic progenitor cells into the cartilage to initiate ossification [7,8,10]. Thus, the vessel that enters the ossifying cartilage, through NF, develops into a nutrient artery at a later stage. Nutrient foramina are initially horizontally placed and become obliquely oriented due to unequal growth at both the ends of bone. Thus, they lie directed opposite to the growing end [9]. The nutrient artery of the diaphysis, usually single but sometimes double, may be considered the major supply to the blood vessels of the bone marrow [7] and is generally regarded as contributing 50–60% of the total blood supply of the bone [11]. In the present study, all radii had NF directed proximally or to the elbow, that is, no anomalous openings. About 99% of the radii had single NF and double foramina were found only in 1% of bones. These findings corroborate the results of studies done on Indian and other populations as well [12-16]. Thus, it becomes essential to safe guard the area of diaphysis of radius containing nutrient foramina to preserve its blood supply while performing surgeries, as shaft was found to have single nutrient source most commonly.

Menck *et al*. [17] and Giebel *et al*. [18] demonstrated that periosteal and endosteal supply for forearm bones is derived from anterior interosseous artery and sometimes from posterior interosseous artery, in case of radius. This corroborates with our study, which shows that majority of NF were on anterior surface, followed by interosseous border and few (8%) on posterior surface. It can be deduced from our study findings

Table 1: Mean length, range of distance of NF from proximal end, and FI of bones

Side of the bone	ML with SD (cm)	Range of DFL	MFI with SD
Both sides	23.37±1.65 cm	5.0–11.7 cm	34.24±4.75
Right	23.50±1.65 cm	5.2–11.7 cm	34.86±5.22
Left	23.26 cm±1.66 cm	5.0–11.5 cm	33.69±4.24

ML: Mean length, DFL: Distance from lower end, MFI: Mean foraminal index, SD: Standard deviation, cm: Centimeter

Table 2: Classification of bones based on foraminal index

FI	Number of bones	Percentage
Type I (<33.33%)	97	48.5
Type II (33.34–66.6%)	103	51.5
Type III (>66.67)	0	0

FI: Foramina index

Table 3: Location of nutrient foramina over the shafts of radii

Location of foramina	Number of bones	Percentage
IB	41	20.5
AB	27	13.5
AS	117	57.5
PS	16	8
PB	1	0.5

IB: Interosseous border, AB: Anterior border, AS: Anterior surface, PS: Posterior surface, PB: Posterior border that most of bones (92%) had NF oriented, in transverse disposition, extending from anterior border to interosseous border. These findings are similar to those of Giebel *et al*. [18] and MysorekarVR [12].

Information to help locate the NF along the length of bone shaft can be used to precisely locate the nutrient artery in the majority cases, while performing fracture repair, bone grafting, reconstruction procedures, etc. Mean foraminal indices of radii from our study were in agreement with those of studies on Indian population but slightly differed with those of Brazilian population [16], which had Mean FI of 35.7±5.6. This is because bone length tends to differ between populations, especially in the distal segments of limbs bones [19].

All radii in the study had NF located in the upper half of the bone and never in the distal radius (Tables 1 and 2) and majority of bones had NF on anterior surface but never on lateral surface. These results are similar to other studies based on Indian, Caucasian, and European population [12-18,20].

Knowledge of blood supply to forearm bones is useful in minimizing damage to donor site and obtain viable grafts [18]. This can be explained with the help of studies on osteocutaneous radial forearm free flap (OCRFFF), which is now being considered more effective for maxillofacial reconstruction [21]. In a study to evaluate the merits of OCRFFF, by Kim *et al*. [21] and Shnayder *et al.*[22], maximum length of radial bone graft taken was up to 11 and 12 cm, respectively. In this surgical procedure, bone is harvested between pronator teres and brachioradialis insertions and lower 2.5 cm of bone needs to be retained for internal fixation of bone [22]. Such a bone harvest is likely to encroach on NF area and damage the major source of blood supply to the donor site, given the average length of radii (Table 1) and distance of NF from lower end of bone in our population [13,14]. Moreover, thickness of radius decreases proximally and anterior border is obliquely oriented, which had NF in 13.5% of bones in the present study, possibility of damaging NA is more as surgeon goes more proximally. These conclusions may be supported by the finding of Kearns *et al.* [23], who opined that rates of radial fracture following OCRFFF harvest range from 0% to 18% with rates in female patients being as high as 32% and harvesting a smaller bone segment was suggested to reduce the risk of pathological fracture.

Therefore, it is preferable to be aware of parameters/length of bone and topography of NF, identified by population-specific studies, to acquire a viable graft and to minimize donor site morbidity.

CONCLUSION

The present study evaluated the length of the bone, topographical distribution of nutrient foramina of radii of South Indian population. It was found that many findings corroborated with those of the previous studies but slightly differed with those of other population-specific studies. An effort was made to highlight the importance of population-specific parameters of bones while obtaining radial bone grafts. The present study contributes to the existing literature on average length of adult radii and distribution of NF of adult radii in the South Indian population.

AUTHORS' CONTRIBUTIONS

1st author – Formulating study plan, Review of literature, Measurements.

CONFLICTS OF INTEREST

Declared none.

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