Anatomic bases of medical, radiologic and surgical techniques

Arterial blood supply of the proximal humeral epiphysis

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Received August 30, 2000 / Accepted in final form March 11, 2001

Key words: Upper humeral epiphysis - Vascularization - Artery - Necrosis

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Abstract

The arterial blood supply of the proximal humeral epiphysis is known to derive mainly from the anterior humeral circumflex a. (ACA), but this description may minimize the role of the posterior circumflex humeral a. (PCA). The studies of Laing [9] and Gerber [3] emphasized the role of the ACA and of its branches, the ascending anterolateral artery and arcuate artery Thus, this description could not explain either the necrosis or the absence of necrosis in all the cases of fracture or dislocation of the glenohumeral joint. The evaluation of the risk of a vascular post-traumatic necrosis of the humeral head requires a knowledge of its arterial vascularization, and the aim of this study was to determine the respective areas of vascularization of both the humeral circumflex aa. 32 shoulders of adult cadavers were studied the ACA and the PCA were injected with latex containing two differently colored fluids. The proximal humeral epiphysis was removed with the arteries. The extra-osseous vessels and the coloration of the capsule were noted then the epiphysis was sectioned in 5 mm horizontal scans, and the bone staining was studied in order to define the distribution of the arterial supplies. The origin of the ACA and PCA was common in only 10 cases. The mean diameters were ACA 0.8 mm (0.3 to 2) and PCA 2.1 mm (1.5 to 4). The subchondral bone was colored in 29 specimens by the PCA, and by both the ACA in the cranial part and PCA in the caudal part in 3. The apex of the head was colored by the ACA in 7 cases, the PCA in 7 and both ACA and ACP in 1 case the head was colored by the PCA in 17 and the ACA in 12 cases the lesser tubercle by the ACA in 23, the PCA in 2 and both arteries in 7 cases the greater tubercle by the PCA in 19, the ACA in 5cases and both in 1 case the intertubercular groove by the ACA in 29, the PCA in 1 and both arteries in 2 specimens. The arcuate a. was distributed along the metaphyseal side of the epiphyseal plate, and small branches crossed the plate to reach the epiphyseal side and give numerous anastomoses to the branches of the ACA or the PCA. The diameter of the ACA was constantly smaller than that of the PCA. Exclusive vascularization of the humeral head by the ACA was not confirmed. The roles of both the ACA and PCA remain important, and must be taken into account in evaluating the risk of necrosis after a fracture, by carefully considering the topography of the separation and the displacement of the different parts.

Fractures of the proximal epiphysis of the humerus carry a risk of aseptic avascular necrosis of the humeral head. A knowledge of the vascularization of the epiphysis is helpful for the understanding of the risk and the choice of treatment. The studies on this subject, and particularly those of Gerber [3] and Laing [9], have emphasised the presence and the role of the intra-osseous aa. coming from the anterior circumflex humeral a. (ACA), and especially the branches of the lateral ascending a., which runs along the lateral edge of the intertubercular groove, and of the arcuate a., which follows this artery after its penetration into the bone. Thus, the essential role attributed to these arteries may not explain all the observed cases of necrosis or, conversely, the absence of necrosis in some cases of fracture-dislocation that could destroy this anterior arterial blood supply. Therefore, the role of the posterior circumflex humeral a. (PCA) must be closely considered. These authors have studied the intraosseous vessels, and our study aimed to determine the vascularization areas of the arteries after coloration by selective catheterization. The reported data concerned three segments of the ACA and PCA the trunk, from the origin to the subperiosteal division, the subperiosteal network and the anastomosis, and the intraosseous distribution. Some hypotheses about the effects of the fractures in relation to the vessels are proposed. This study defines the important part of the arterial blood supply carried by the PCA, especially to the subchondral bone of the humeral head around the center of the humeral head, which is vascularized by both the ACA and PCA.

Material and methods

Thirty-two shoulders of adult embalmed cadavers, free of skin scar, were dissected.

A large skin flap was resected at the anterior side of the shoulder. The anterior part of the deltoid m. was detached from the clavicle and from the anterior edge of the acromion. The tendons of the coracobrachialis m. and of the short head of the biceps brachialis m. were sectioned from the coracoid process and retracted distally in order to expose the axillary a. and the origins of the humeral circumflex aa. Selective catheterization was performed with irrigation of an isotonic saline solution, and colored latex was injected with red eosin into one circumflex a. or with methylene blue into the other, according to a random choice. If the origins from the axillary a. of ACA and PCA were separate, the axillary a. was ligated in three places in order to create two chambers of injection when the ACA and PCA originated from a common trunk, the axillary a. was ligated above and below the arterial trunk and the PCA was selectively catheterized (Fig. 1).

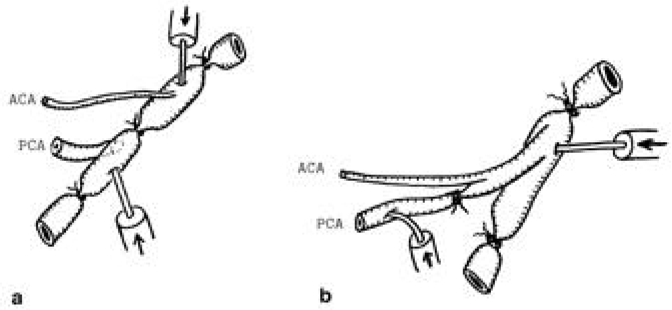


Fig. 1 a, b a. In 22 specimens the origins of the ACA and PCA were separate. Two chambers of injection were created in order to perform selective catheterization of the arteries. **b.** In 10 specimens, the arteries originated from a common trunk. The PCA was directly injected

The injection was made under manual pressure, until the colored latex was seen in the circumflex humeral vv. In 7 cases, direct injection of coloured latex (green) was made into the suprascapular a.

Then the tendons of the rotator cuff and the capsule were sectioned, and the whole proximal extremity of the humerus was removed and frozen in order to promote hardening of the latex. The circumflex aa. and the corresponding segment of the axillary a. were removed with the bone. Twenty-four hours later, the length and diameter of the circumflex aa. were measured with a calliper, and their origin as a common trunk or separately from the axillary a. was noted. The macroscopic aspects of the collateral and terminal branches to tendons, capsule, bone, and their anastomoses were observed.

The bone was sawn into at least 5 mm thick horizontal scans, and the areas of bone arterial vascularization were studied at the humeral head (top, center, subchondral bone), the greater and lower tubercles, the intertubercular groove and the surgical neck (Fig. 2).

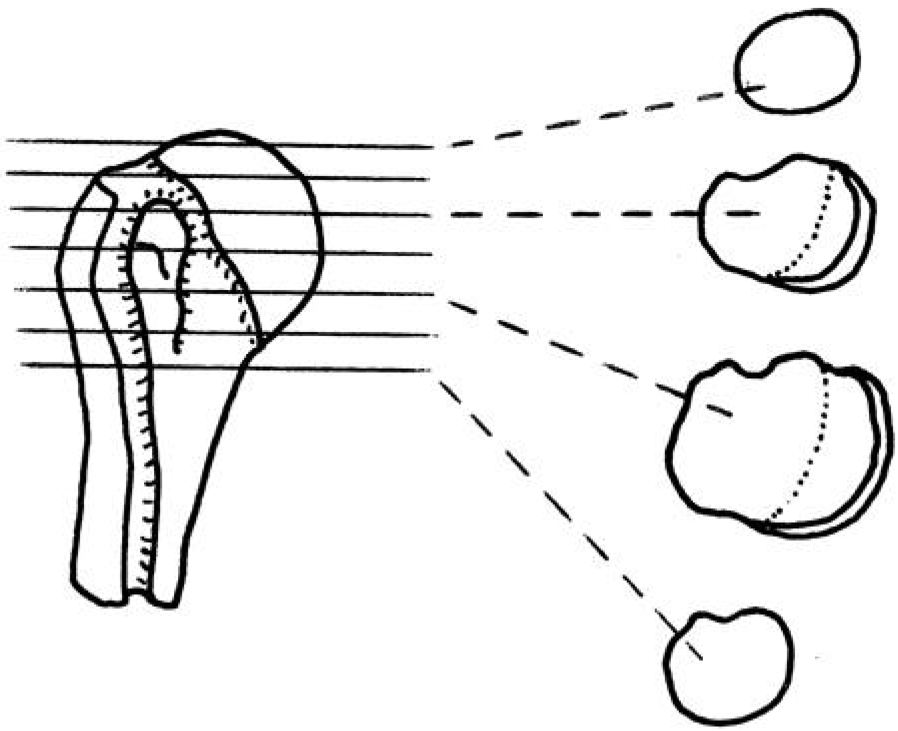


Fig. 2 The upper extremity of the humerus was sectioned in 5 mm-thick horizontal scans

Results

Origins of the circumflex humeral aa.

A common trunk (collateral branch of the axillary a.) was found in 10 cases the origins of the arteries were separate in 22 cases (Fig 1). In 15 cadavers studied on both sides, a symmetric aspect was present in 12 cases, a common trunk in 3, and separate origins in 9. In the 3 remaining cases, a common trunk was only present on one side.

Anterior circumflex humeral a. (ACA) (Fig. 3)

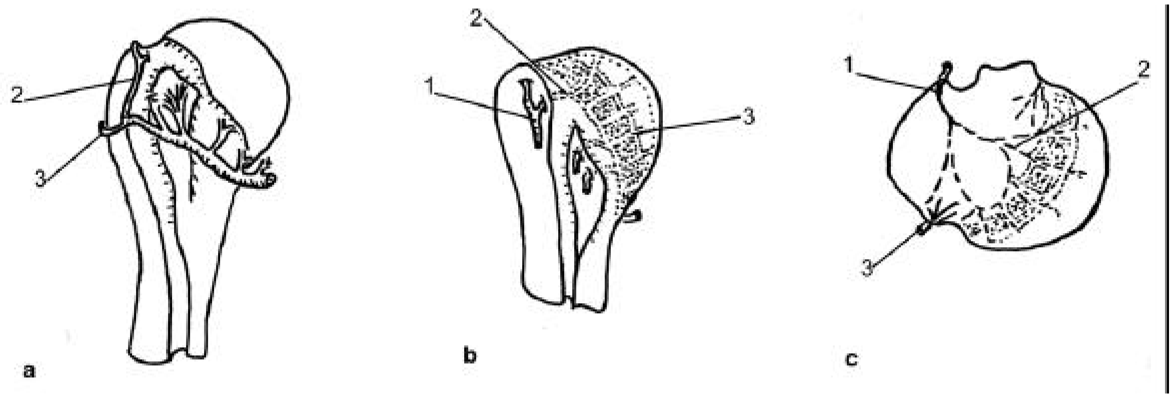


Fig. 3 a-c **a.** 1, ACA 2, lateral ascending branch 3, lateral branch (anastomosis to the PCA). **b.** 1, lateral ascending branch 2, arcuate a. 3, branches of the arcuate a. through the epiphyseal plate **c.** 1, arcuate a. 2, branches of the arcuate a. through the epiphyseal plate 3, small branch of the PCA penetrating in the anatomical neck along the insertion of the capsule

The mean diameter was 0.8 mm (0.3 to 2 mm). The mean length was 18.3 mm (7 to 28 mm), between the origin and the first division of the artery.

The collateral branches were articular branches that penetrated into the inferior part of the capsule of the glenohumeral joint, muscular branches for the subscapularis m. and tendon, osseous branches for the lower tubercle, and one short medial ascending branch that reached the medial edge of the intertubercular groove, and penetrated the bone at the level of the middle of the sulcus.

The terminal branches were a lateral ascending branch which followed the lateral edge of the intertubercular groove, and an anastomotic branch which ran around the surgical neck to reach a corresponding branch from the PCA. The ascending lateral a. penetrated the bone at the top of the intertubercular groove, above the lateral edge in 12 cases, or 9 mm (3 to 16) below the level of the top of the groove in the other cases. Some small branches were occasionally seen for the tendon of the long head of the biceps brachialis, the anterior bursa, the tendons of the latissimus dorsi or pectoralis major, and for the superior and anterior parts of the capsule of the glenohumeral joint.

Posterior circumflex humeral a. (Fig. 4)

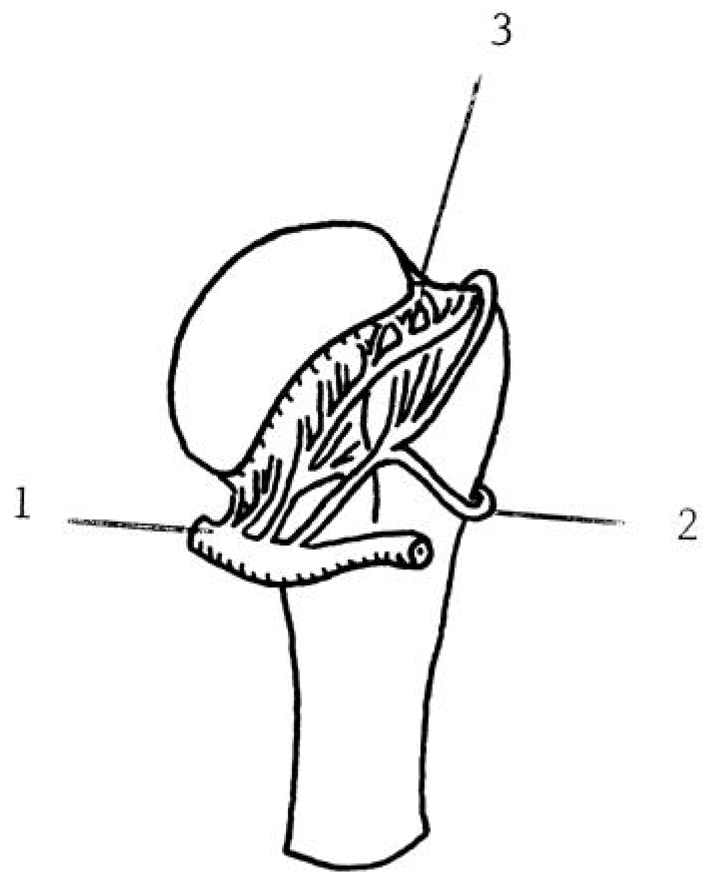


Fig. 4 1, PCA 2, lateral branch anastomosis to the ACA 3, branch of the PCA around the posterior side of the anatomic neck

The origin of the PCA from the axillary a. was separate from that of the ACA in 19 cases. A common trunk was seen in 10 cases. Some unusual origins were seen from the profunda brachii a. in 1 case, or from the lateral thoracic a. in 1 case. In one case the PCA was absent. The mean diameter was 2.1 mm (1.5 to 4) the mean length was 33.4 mm (12 to 90). If the separate PCA originating from the axillary a. is only considered, the mean length became 28 mm (12 to 37).

The PCA ran backward through the quadrilateral space, and divided into two branches one to the deltoid m. and the other to the upper humeral epiphysis. This branch gave numerous small branches that penetrated the inferior, posterior and superior parts of the capsule, or the posterior and superior parts of the humeral neck and of the greater tubercle a few branches to the tendons of the supraspinatus, infraspinatus and teres minor mm. were seen.

The paths of bone vascularization

The paths of bone vascularization differed according to the types of branches of both the ACA and PCA. The capsular branches penetrated the superficial side of the capsule at a few mm from its insertion on the bone, then crossed the capsule and reached the bone at the deep side of the capsule. This structure created an arterial circle around the humeral head, carried by the capsule, mainly developed in the inferior and posterior part of the capsule the branches destined to the tendons of the cuff divided in the thickness of these tendons, and penetrated the bone at their bony insertions. The osseous arterial branches had a subperiosteal course and gave smaller branches before penetrating the cortical bone.

The intraosseous arterial blood supply

The bone morphology on the scans presented high-density areas the subchondral bone of the head, the centre of the head - limited laterally by the epiphyseal plate - and the greater tubercle. The cortical bone was thick along the intertubercular groove, in the posterior part of the greater tubercle, and thin in the anatomic neck. In the central part of the metaphysis, the trabecular bone showed a low density (Fig. 5). The radiographs of the bone scans (Fig. 6a, b) confirmed these aspects.

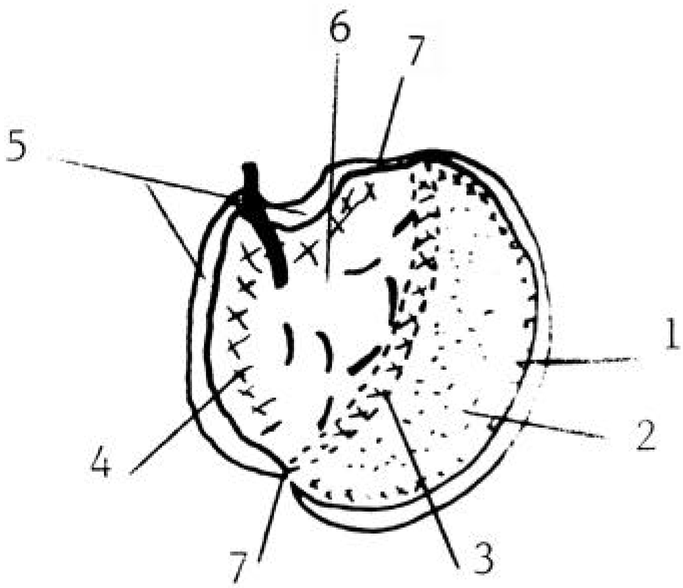
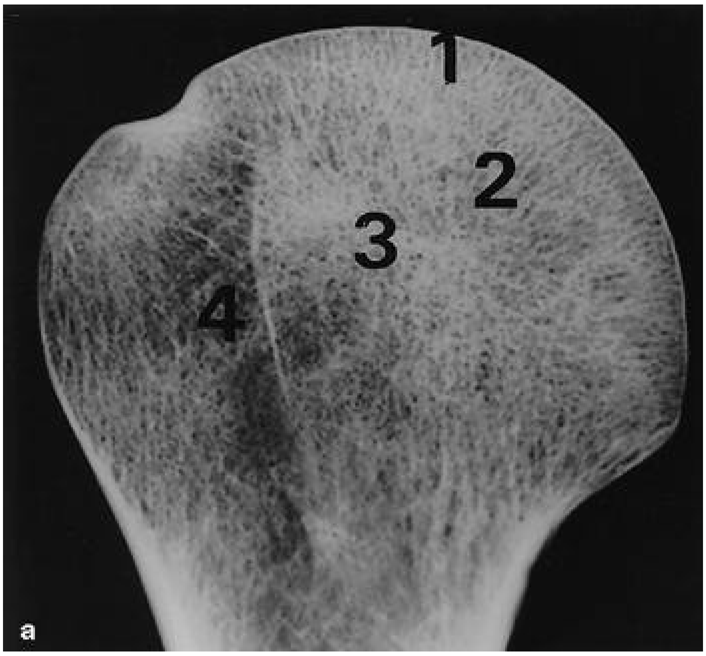


Fig. 5 The intrinsic bone morphology as observed on the scans. The zones of high density of the proximal humeral epiphysis 1, the subchondral bone of the humeral head 2, the center of the humeral head 3, the lateral limit of the humeral head, the epiphyseal plate 4, the trabecular bone of the greater tubercle 5, the cortical bone of the greater tubercle and of the intertubercular groove The zones of low density and weakness 6, the trabecular bone of the metaphysis 7, the cortical bone of the anatomic neck



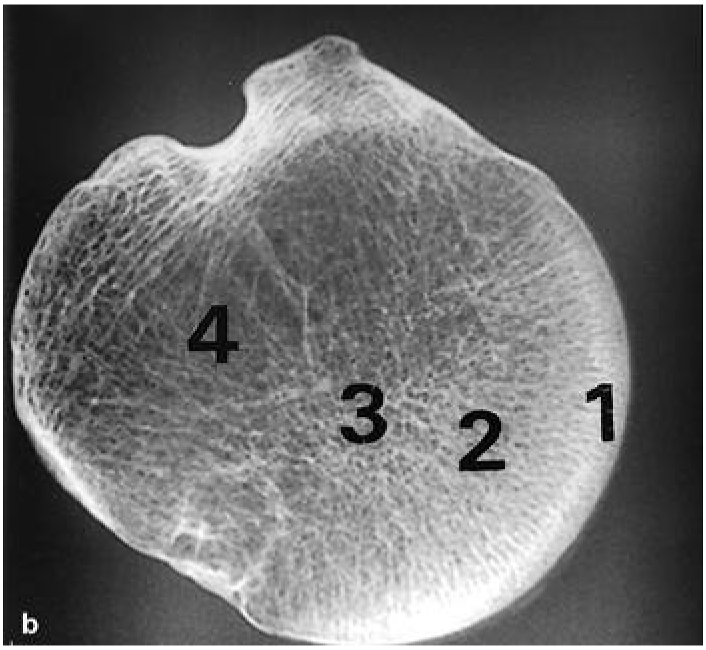


Fig. 6 a, b a. Anteroposterior X-ray view of the proximal humeral epiphysis on dry bone. The areas of high density that are related to the arterial blood supply 1, the subchondral bone of the head 2, the trabecular bone of the center of the head 3, the calcified epiphyseal plate the zone of low density 4, the trabecular bone of the metaphysis. **b.** The radiologic aspect of the bony scans on dry bone the areas of high density that are related to the arterial blood supply 1, the subchondral bone of the head 2, the trabecular bone of the center of the head 3, the calcified epiphyseal plate the zone of low density 4, the trabecular bone of the metaphysis

In the area of vascularization by the ACA (Fig. 3), the observed intraosseous vessels were mainly the branches of the arcuate a. Its branches divided along the metaphyseal side of the epiphyseal plate and fanned out in the cancellous bone. These vessels were seen on the different scans, and anastomosed with arterial branches located on the epiphyseal side of the epiphyseal plate. These anastomoses joined two networks of the two sides of the epiphyseal plate, and showed direct intraosseous anastomoses between the branches of the PCA and the osseous, tendinous or capsular branches of the ACA.

The intraosseous vessels arising from the branches of the PCA were not so well identified, because they had a short course after their penetration at the deep side of the insertion of the capsule. The peripheral zones, close to the insertion of the capsule, were constantly rich in small vessels coming from both the ACA and PCA.

The vascularization areas were observed on the serial scans (Fig. 7)

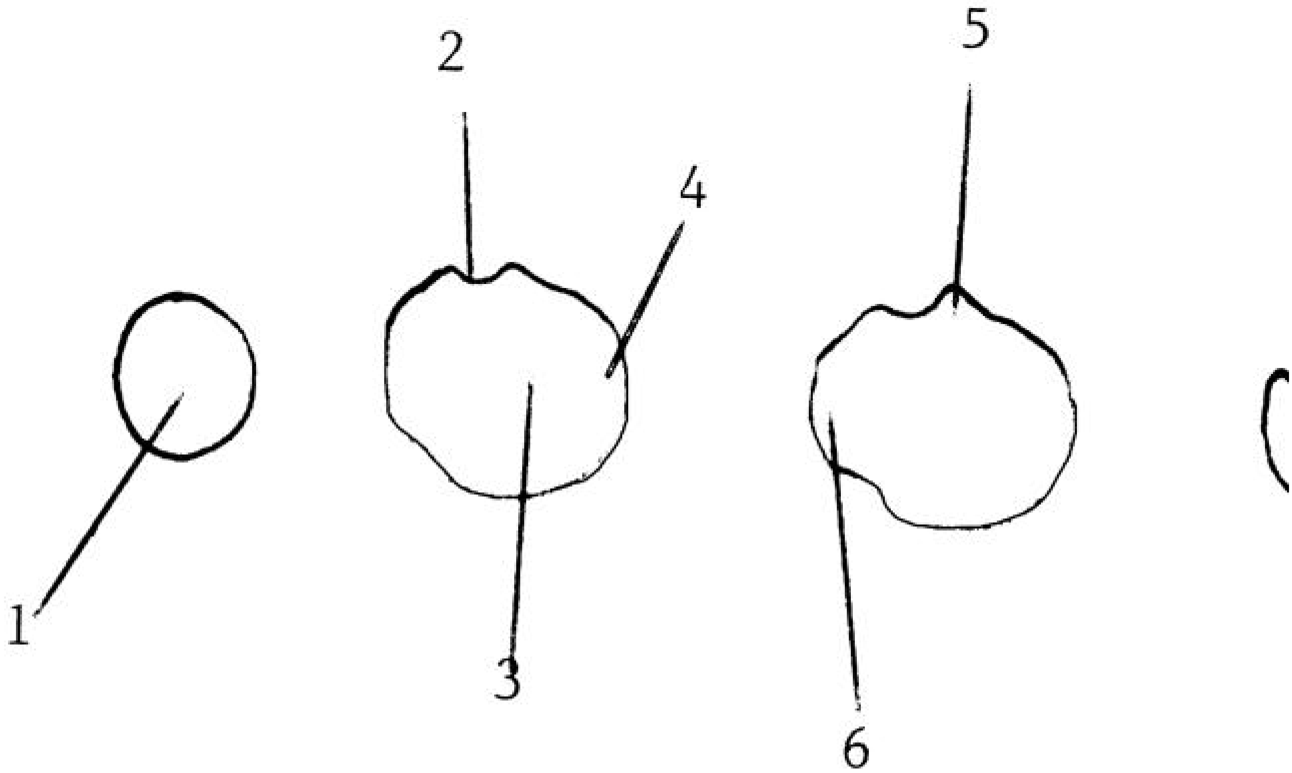


Fig. 7 Distribution of the arterial blood supply in the upper epiphysis of the humerus *1,* The top of the head ACA 7, PCA 16, ACA + PCA 1 *2,* the intertubercular groove ACA 29, PCA 1, ACA + PCA 2 *3,* the center of the head ACA 12, PCA 17, ACA + PCA 3 *4,* the subchondral bone PCA 29, ACA + PCA 3 *5,* the lesser tubercle ACA 23, PCA 2, ACA + PCA 7 *6,* the greater tubercle ACA 5, PCA 19, ACA + PCA 1 *7,* the surgical neck ACA 3, PCA 17, ACA + PCA 12

The top of the humeral head was colored by the PCA in 16 cases, by the ACA in 7 cases, in 1 specimen by both arteries, and the coloration was too weak in 8 cases for a reliable interpretation. The center of the head was colored by the PCA in 17 cases, and by the ACA in 12 cases. In 3 cases, the PCA gave the coloration of the cranial part, and the ACA colored the caudal part of the head. Among these 3 cases, only 1 showed the same distribution of the colored injected fluids in the subchondral bone. The subchondral bone was colored by the PCA in 29 cases, and in 3 cases by the PCA in the cranial part and the ACA in the caudal part.

The greater tubercle was colored by the PCA in 19 cases, 5 times by the ACA and a lateral and superior branch of the lateral ascending a., and by both arteries in 8 cases. The lesser tubercle was colored in 2 specimens by the PCA, in 23 cases by the ACA, and by both arteries in 7 cases.

The intertubercular groove was coloured by the ACA in 29 specimens, by the PCA in 1 case, by the PCA in the cranial part and the ACA in the caudal part in 1 case, and 1 specimen showed coloration of the medial part by the ACA and of the lateral part by the PCA.

The surgical neck of the humerus was colored by the PCA in 17 specimens, the ACA in 3 and both arteries in 12.

Anastomoses (Fig. 8)

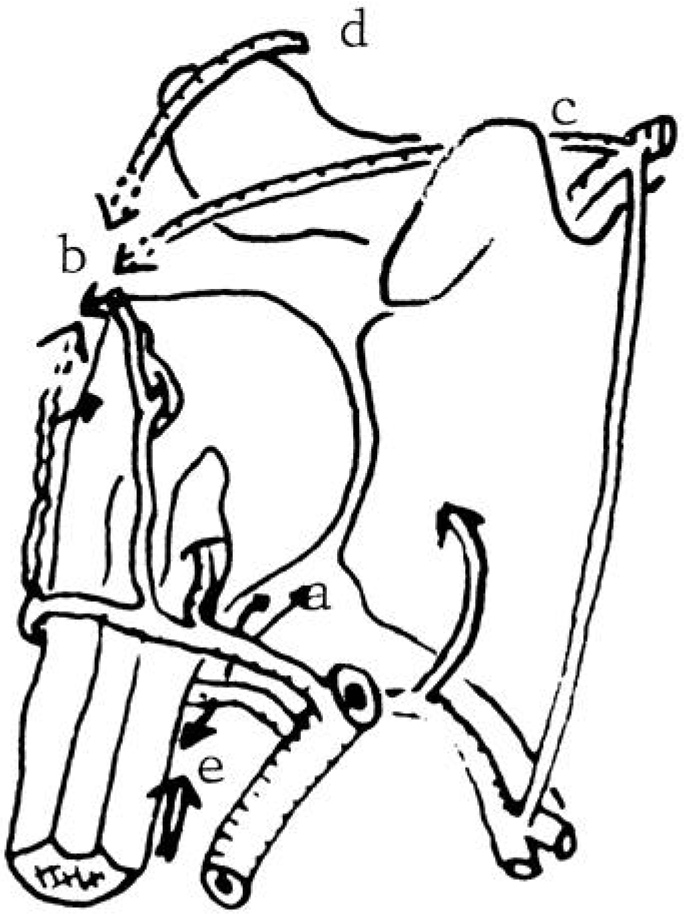


Fig. 8 Extraosseous anastomoses were found between the branches of the ACA and PCA, at the intraarticular side of the capsule around the anatomic neck of the humerus (a), and in the tendons of the rotator cuff around the tuberosities. Subperiosteal anastomoses were mainly developed along the lateral side of the greater tubercle (b). Some anastomoses were seen with the terminal branches of the suprascapular (c), thoracoacromial (d) and deep brachial (e) aa. The selective catheterization of the suprascapular a. did not color the humeral head

The extraosseous anastomoses were found between the ACA and PCA, and with some other branches of the axillary a. (thoracoacromial, suprascapular, subscapular aa.), or with retrograde ascending branches of the deep brachial a. Thus, selective catheterization of the suprascapularis a. never colored the humeral head. The extraosseous anastomoses between the ACA and the PCA were found in the tendons of the rotator cuff, in the capsule, and mainly in its inferior part where a rich network was seen at the deep side. The subperiosteal anastomoses were developed at the lateral face of the surgical neck and at the lateral face of the greater tubercle. The intraosseous anastomoses have been previously described through and around the epiphyseal plate.

Discussion

The small diameter of the ACA in comparison to that of the PCA does not agree with the description of a large dominant blood supply to the humeral head due to the ACA, as described by Brooks [1], Gerber [3] and Laing [9]. The ACA is equally exposed to traumatic or iatrogenic peroperative injuries, so that the rate of humeral head a vascular necrosis ought to be very high. Of course, after opacification, the decalcification of the head will show the arcuate a. as the main vessel individualized in the epiphysis. Thus, the blood supply carried by the PCA must be taken into account, because of the rich network of branches that penetrate into the bone around the anatomic neck. Fischer et al [2] have emphasized the rich network of anastomoses in the upper humeral epiphysis, and showed that, in the child, the vessels are separated by the growth-plate, which becomes crossed and surrounded by the vessels after its fusion. Our study showed that the main arterial blood supply to the subchondral network of the humeral head is carried by the PCA.

The surgical neck, in the dry bone, presents numerous foramina of penetration of the short branches of the arterial circle between the ACA and PCA [4], and the anatomic neck also shows a great many vascular foramina. The presence of the developed intraosseous network and intracapsular anastomosis between the ACA and PCA may explain why the head survives when a fragment of neck is attached with it, which means that a part of the capsular insertion is preserved.

The mean diameter of the PCA was three times superior to that of the ACA. The PCA ended by division into two branches, one destined to the deltoid m., but the other carrying an important blood supply to the bone. The distribution of the areas stained by the ACA and the PCA showed the important role of both of these. The vascular effects of an injury of the upper humeral epiphysis may be caused by a direct injury of the trunks of the arteries, by destruction of the subperiosteal vessels, by interruption of the intraosseous vessels, or by simultaneous lesions of two or three of these mechanisms together. In the cases of fractures with a major displacement, or with dislocations, all three mechanisms of blood supply interruption may be involved.

The injections of the suprascapular a. never colored the humeral head, but after an injury the anastomosis may be thought to be most developed and efficient. The insertions of the tendons carry some arterial vessels that penetrate into the bone, but the possibilities of substitutionare only hypothetical [11, 12]. The subperiosteal vessels may be injured by a fracture, even if undisplaced. The persistent patency of a subperiosteal vessel in relation to the fracture is also a hypothesis, that is not sustained by the necrosis that may be occasionally observed after some undisplaced or slightly displaced fractures [4, 14].

The effects of a fracture concern the intraosseous vessels. Any fracture of the anatomic neck will separate the head from its arterial blood supply, because it will remove the center of the head and the epiphyseal plate from the humerus. The interruption of the blood supply is unavoidable in this case, and the head survey will only be possible if some parts of the capsule remain attached to a fragment of the neck separated with the head [1, 6, 10, 13, 14], or if some tendinous insertions remain present on a fragment of tuberosity separated with the head. Later, a restored vascularization may be expected, because of local neo-angiogenesis in the fracture-healing zone. Thus, the conditions of survey of the humeral head need a sufficient blood supply during this healing period. The rate of necrosis seems less high in the cases of impacted valgus fractures, when the displacement is slight, without shearing between the metaphysis and the epiphysis, completing the previous observations of Jakob [7].

The intraosseous vessels have the same arrangement as the trabecular bone, and the different supplies to the head or the tubercles may be separated. The decreased density of the bone with age creates a zone of weak resistance between the tubercles, as seen on the radiographs when the trabecular system is altered, the narrow cortex of the diaphysis, and the dense bone of the epiphyseal plate and of the center of the head [5]. These structures may be much more easily separated in the elderly, and this will cause interruption of the blood supply to the head. The remodeling activity of the bone and the number of vessels in the subchondral bone will decrease from 30% between the teenage and the sixth decade, and is slightly re-increased later [8], so that the risk of avascular necrosis of the periphery of the head appears greater with age because of the poor remaining blood supply.

Conclusion

Both the ACA and PCA participate in the vascularization of the upper humeral epiphysis. The interruption of the blood supply to the humeral head probably occurs at the time of the injury (fracture or dislocation or combined fracture-dislocation), or during secondary displacement of the fragments in reduction. These data may help in the therapeutic decision between a conservative treatment that must avoid increasing the vascular injuries or a prosthetic arthroplasty, with a close relation to the type of bone injury and the age of the patient.

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Surg Radiol Anat 23: 185-190