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Arterial supply of forearm bones and its importance for the operative treatment of fractures

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Summary: The operative exposure of a fracture in an osteosynthesis causes disturbances in the blood supply, which often leads to a prolonged process of healing or even to healing problems, a fracture non-union, which is frequently located at the forearm. In order to damage the supplying vessels as little as possible, the position, direction and penetration of the arteries of radius and ulna are demonstrated and systematised in this study. Near the elbow arteries, coming from large adjoining vessels, penetrate the area of the capsular insertion. The nutrient arteries enter both bones in the second proximal quarter of diaphysis, at the radius from anterior to medial, at the ulna from anterior to anteroradial. Small vessels, which penetrate closely proximal to the articular surface in order to supply the distal forearm bones, come from an anastomosis between the radial, the interosseous and the ulnar arteries. In this study access vessels, choice and position of implants will be discussed.

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Vascularisation artérielle des os de l'avant-bras et son importance pour le traitement des fractures

Résumé : L'abord d'un foyer de fracture en vue d'une ostéosynthèse perturbe la vascularisation artérielle des os, ce qui allonge la durée du processus de consolidation, cela peut même conduire à une pseudarthrose dont on connait la fréquence élevée au niveau de l'avant-bras. Afin de limiter autant que possible les conséquences vasculaires de l'abord chirurgical, nous avons analysé et systématisé dans cette étude la position, la direction et les zones de pénétration des artères dans le radius et l'ulna. Au voisinage du coude les aa. nourricières des os provenant des vaisseaux voisins, pénètrent dans les os au niveau de la zone d'insertion capsulaire. Les aa. nourricières pénètrent les deux os de l'avant-bras au niveau du second quart proximal de la diaphyse; au niveau du radius cette pénétration se fait en avant et en dedans, au niveau de l'ulna en avant et en dehors. Les petits vaisseaux de la partie distale des deux os de l'avant-bras pénètrent juste en amont des surfaces articulaires et viennent d'une anastomose entre les aa. radiale, interosseuse et ulnaire. Dans cette étude l'abord des vaisseaux, le choix et la position des implants sont discutés.

Key words: Ulna — Radius — Blood supply of bones — Osteosynthesis

Long tubular bones tend to break frequently because of their function as levers. That is why these bones often are the reason for traumatologic and orthopaedic operations. Because of the long time between cause and consequence, aseptic bone necrosis, also caused by the treatment, is imputed generally to fate or the accident rather than to the surgeon. But in most cases mistakes either in the indication or in the operation are the main reasons for healing disturbances after osteosyntheses because of devascularization of unfit fractures [8].

The nutritive bone vessels are of special importance both for the healing of fractures and for the prevention of avascular bone necrosis [3, 22]. It is true that metaphyseal and epiphyseal vessels, together with the periosteum, maintain the blood supply of bones after an interruption of nutrient arteries, however not to that extent that healing disturbances could be avoided [2, 14, 11, 18, 19]. Whereas at the lower extremity the position of implants is given by load or muscle draught, at the upper extremity, depending on position or kind of fracture, stabilisation can be reached by different ways, by various kinds or positions

of the implants, so that the patient will be able perform a physiotherapy. This applies especially to the forearm, where the radius rotates 160° around the ulna.

As blood supply of both forearm bones is endangered because of the small contact surfaces after a fracture, special care should be taken during the operation to avoid additional damage, especially to these bones. The choice of both the access and of the implants as well as knowledge of the extraosseous course of bone arteries, as far as they are systematic, are the preconditions for this procedure. This study intends to increase this special knowledge in particular.

Materials and methods

In order to depict forearm bones, six arms (3 on the right, 3 on the left) of four fresh, non preserved cadavers were examined. First the brachial artery was dissected upwards and a cannula was inserted, fixed by suture. Ringer's solution was perfused and traumatized muscle arteries were tied. Radius and ulna were stabilized with Kirschner-wires for further preparation.

In order to make the corrosion preparation, epoxide was injected consisting of 60 parts of epoxide E20 (BIODUR™ E20), 27 parts of hardener E2 (BIODUR™ E2) and 13 parts of MEK (methylethylketone, a softening agend). After the removal of the cannula and occlusion of the brachial artery the specimen was placed in a bag filled with water and kept for two days at a temperature of 130°F for polymerisation of the resin. After that the specimen was cut up without destroying the respective structures, followed by maceration in potash lye (10%) for 4-6 days. Having been intensively rinsed in water, the specimen desiccated for some days and was fixed with clear varnish.

Results

Radius

Fine arteries coming from both the radial and the recurrent interosseous arteries run towards the radial head - in all specimens tested - and penetrate the bone distal to the articular circumference. The joint surface itself is free of vessels (Fig. 1). The arterial net penetrates the whole circumference directly distal to the annular ligament in an area of about 0.6 inches.

At two forearms from the same body neither a radial nutrient artery nor a nutrient foramen was found. All other specimens had a nutrient radial artery, coming from the anterior interosseous artery, which always penetrated the second proximal quarter of the diaphysis of the radius, from anterior (1 x), anteromedial (1 x) or medial (2 x). In all cases this short vessel, having reached the bone, turns laterodistal and enters the nutrient canal at an acute angle, in the direction of the elbow (Fig. 2).

In two specimens the distal forearm was dissolved by the lye, so that the arterial vascularization of the bones could not be examined. In the other preparations the distal radius was supplied by a volar and a palmar arterial arch, both connected with the radial, the anterior interosseous and the ulnar arteries. These arches are placed at the area of radial and ulnar metaphyses. From here anastomosing branches run downwards, penetrating the radius at the boundary between bone and cartilage, except the ulnar incisure (fig. 3).

Ulna

Short branches, penetrating the bone near the cartilage, supply the olecranon. They arise from the adjoining ulnar recurrent artery and from the interosseous recurrent artery, which run medial and lateral to the bone. Extraosseous connections between these vessels could not be found. For the most part fine vessels, arising from the ulnar recurrent artery, could be detected, which entered the proximal ulna from the front near the articular cartilage (Figs. 1 and 4).

In two specimens we could not find vessels supplying the ulnar diaphysis, just as at the radius. All other forearms showed an entry of the ulnar nutrient artery into the second quarter of the diaphysis from anterior to anteroradial. In one case the nutrient artery came from the recurrent ulnar artery, in all other cases it came from the anterior interosseous artery. The vessels, approx. 1 cm long, run to distalmedial, turning then in an acute angle into the ulnar nutrient canal, directed to proximal (Figs. 2 and 5).

Branches of the anastomoses between the three forearm arteries - the radial artery, the ulnar artery, and the anterior interosseous artery - supply the distal ulna. From every side these branches penetrate the caput ulnae, only the articular surface and the styloid process are free of vessels (Fig. 3).

Discussion

Apart from biomechanical factors, such as unstabile fracture, blockade by the other bone, numerous divergent muscle insertions, different rotary movements at the proximal and at the distal radioulnar joints, the pulling effect of the interosseous membrane, the interposition of tissue, etc., the vascularization is as precondition for fracture healing at the forearm of central importance [4, 23]. Whereas accidental destruction of the angioarchitecture cannot be influenced, additional damage may be caused by careless reposition, by the choice of access and of the implant position. Thus, the knowledge of the details of the arterial supply is essential in order to avoid these injuries. Whereas lesions of the nerves become obvious immediately after the operation, lesions of the supplying vessels cannot be recognised before weeks or months because of failing fracture healing. Then other circumstances often are blamed for this.

Whereas the large arteries are scarcely endangered at the usually chosen dorsal and lateral accesses to both forearm bones, the radial artery is especially exposed to damage at the ventral access between the brachioradialis and the pronator teres. Figure 6 shows the line of incision of the most usual ventral access in relation to the forearm arteries.

Radius

An arterial network, arising from the radial recurrent artery and from the interosseous recurrent artery, supplies

the head of the radius [9]. This was also the result of examination of children's forearms [25]. All around the bone the arterial network penetrates directly distal to the annular ligament. In medical literature experts agree on the supply of the proximal radius [9, 16, 21]; just as in other publications, a ramus periostalis of the ulnar artery [16], could not be detected in the present study. In addition to its mechanical function, the annular ligament protects the nearby vessels, which should be paid attention to in operative dissection of the head of the radius. An extensive damage of the arterial network by screws or wires, generally used for the stabilisation of fractures, is not to be expected.

The vessel of the diaphysis always penetrates the radius in the second proximal quarter [6, 17, 24]. In general, there is a single supplying artery, but it may be missing or occur twice, too [13]. The radial nutrient artery comes from the anterior interosseous artery [16, 20, 21]. In accordance with other authors, we cannot confirm Anseroff's [1] result, i.e. that the nutrient artery might pene-

Fig. 1
Right elbow of a 47-year-old man from posterolateral. Arteries of the distal upper arm and of the olecranon are shown. *1*, brachial artery; *2*, radial collateral artery; *3*, penetration of vessels at the lateral epicondyle; *4*, penetration of vessels at the lateral olecranon; *5*, penetration of vessels at the proximal radius

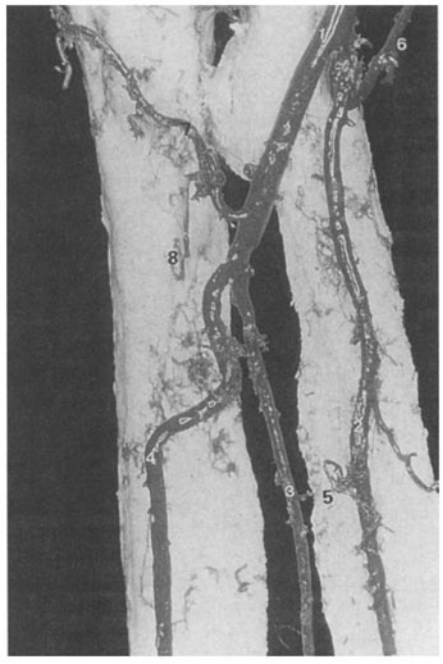

Fig. 2
Left forearm of a 80-year-old woman from anterior. Main arteries of the forearm are shown, as well as origin, course and penetration of radial nutrient artery and ulnar nutrient artery. *1*, brachial artery; *2*, radial artery; *3*, interosseous artery; *4*, ulnar artery; *5*, radial nutrient artery; *6*, radial recurrent artery; *7*, ulnar recurrent artery; *8*, ulnar nutrient artery

Fig. 3
Right distal forearm of a 47-year-old man from posterior. Metaphyseal anastomoses and their branches to radius and ulna are shown. *1*, interosseous artery; *2*, metaphyseal anastomosis; *3*, branches of the metaphyseal anastomosis to the radius; *4*, branches of the metaphyseal anastomosis to the ulna

Fig. 4
Right proximal forearm of a 48-year-old woman from anteromedial. Branches of the ulnar recurrent artery into the olecranon are shown. *1*, brachial artery; *2*, ulnar recurrent artery; *3*, branches from lateral into the olecranon

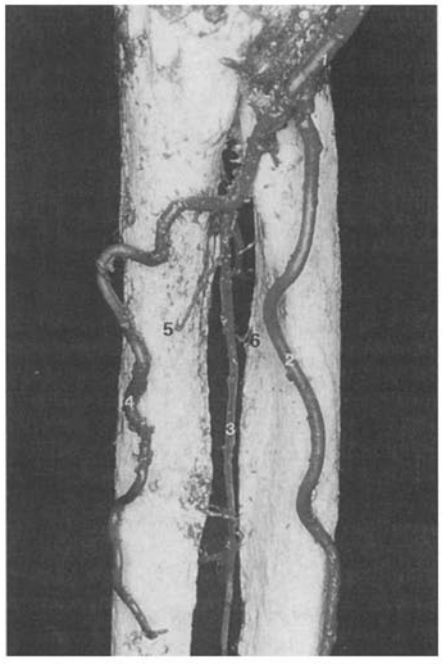

Fig. 5
Left proximal forearm of a 48-year-old woman from anteromedial. Branches of the recurrent ulnar artery into the ulna are shown. *1*, brachial artery; *2*, radial artery; *3*, interosseous artery; *4*, ulnar artery; *5*, nutrient ulnar artery; *6*, nutrient radial artery

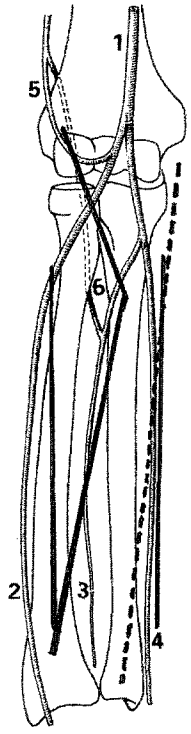

Fig. 6

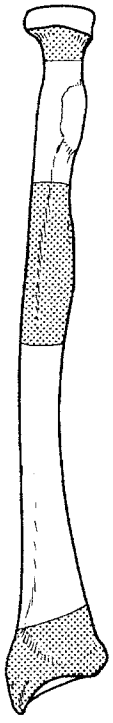

Fig. 7a

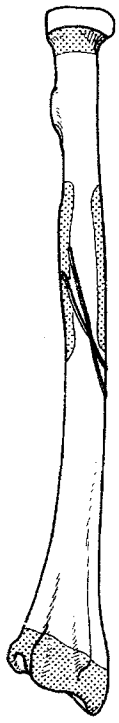

Fig. 7b

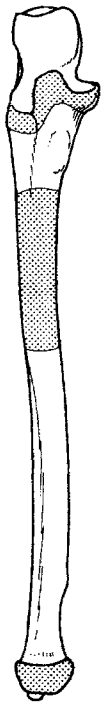

Fig. 8a

Fig. 8b

Fig. 6
Schematic drawing of the forearm arteries of the bone and of the operative access (continuous line: dorsal, interrupted line: volar). *1*, brachial artery; *2*, radial artery; *3*, interosseous artery; *4*, ulnar artery; *5* & *6*, both recurrent arteries

Fig. 7a, b
The *hatched areas* show the regions of possible penetration of arteries supplying the radius. **a** view from the front, **b** view from the back

Fig. 8a, b
The *hatched areas* show the regions of possible penetration of arteries supplying the ulna. **a** view from the front, **b** view from the back

trate the entire middle third of the bone; we rather confirm that - apart from the more proximal position - the dorsoradial area always is without nutrient foramen [6, 17, 24]. That is why the nutrient artery is saved at the dorsal position of the plate, which anyhow is advantageous to the operative procedure (especially at the use of LC-DCP (limited contact - dynamic compression plate)). In medical literature experts share the same opinion [7, 16, 20, 25].

The position of the metaphyseal arc, as shown in Figure 3, is too far upward. This is an artefact, because the shortening of the muscle, as a result of the heat treatment, pulled the anterior interosseous artery upward. The anatomical positions of the dorsal and the palmar anastomoses between the three forearm arteries are on a level with the metaphysis [7].

Figure 7 shows a general idea of the possible positions of penetration of the arteries supplying the radius.

Ulna

In accordance with the literature [16, 25] branches of the ulnar recurrent artery and the recurrent interosseous artery supply the olecranon from medial and lateral. A posterior peritrochlear circulus, as described by Teot [25] in examinations of children did not occur in any of our specimens. Other authors [12, 16], having examined adults, had the same result so that possibly this posterior peritrochlear circle might maintain the supply of the epiphysis during growth and atrophies, having lost its purpose. It is possible that muscle arteries also support the arterial supply of the elbow [14]. The blood supply of the olecranon is hardly jeopardized by the usual methods of osteosynthesis, such as cerclage wire, malleolar screw and posterior plate. The entry of the ulnar nutrient artery was always found from anterior to anteroradial into the second proximal quarter of diaphysis [1, 6, 17, 24]. The vessel usually arises from the anterior interosseous artery, rarely from the ulnar recurrent artery. In general the vessel occurs singly, 6 to 10% of the human beings have a second nutrient foramen [1, 6, 12, 16, 17, 24]. The middle and the distal diaphysis of the ulna there is a hypovascularizised area [5]. The osteosynthesis with a plate is often chosen, for the ulna, as well as for the radius. The dorsal localisation for the plate should be preferred, even if a second access is necessary. Also at the distal end of the ulna there are differences between children and adults: the fine artery, arising from the metaphyseal arch and running to the styloid, as discribed by Teot [25], could not be detected in adult specimens. Because of the ample arterial supply of the distal ulna and of the fact that open reposition is only rarely necessary (usually a percutaneous pinning with wire is sufficient), an iatrogenic damage of the vascularity is only to be expected as an exception.

Figure 8 illustrates the penetration areas of the vessels.

During the operation special care should be taken of the radial and of the ulnar nutrient arteries - also if there are intraosseous anastomoses [2, 10, 14, 18] -, because on the one hand they are very vulnerable because of the angular penetration of the bone and according to animal examinations, on the other hand, they are of exceptional importance for the fracture healing at the diaphysis [5, 26].

References

1. Anseroff NJ (1934) Die Arterien der langen Knochen des Menschen. Z Anat Entwicklungsgesch 103: 793-812
2. Brookes NJ (1971) The blood supply of bone. Appleton Century Crofts, New York
3. Carroll SE (1963) A study of the nutrient foramina of the humeral diaphysis. J Bone Joint Surg [Br] 54-B: 176-181
4. Finkbeiner GF (1980) Pseudoarthrosen und verzögerte Heilung nach Unterarmbrüchen. Unfallheilkunde 83: 353-359
5. Fischer L, Machenaud A, Morin A (1974) Contribution à l'étude de la vascularisation du cubitus. Arch Anat Pathol 22: 261-265
6. Forriol Campos F, Gomez Pellico L, Giamonatti Alias M, Fernandez-Valencia R (1987) A study of the nutrient foramina in human long bones. Surg Radiol Anat 9: 251-255
7. Gelberman RH, Panagis JS, Taleisnik J, Baumgaertner M, (1983) The arterial anatomy of the human carpus. Part I: The extraosseous vascularity. J Hand Surg [Am] 8: 367-375
8. Giebel G, Tscherne H, Oestern HJ, (1984) Fraktur- und Osteotomieheilungsstörungen: Eine Analyse aseptischer Komplikationen. Chirurg 55: 725-730
9. Girard JY, Rogez JM, Robert R, Leborgne J (1995) Vascularization of the head of the radius in the adult. Surg Radiol Anat 17: 41-45
10. Gremigni D, de Faveri Tron M, Faccendi S (1977) La vascolarzzazione arteriosa dell'ulna e del radio nell'Uomo. Arch Ital Anat Embriol 83: 179-188
11. Laing PG (1953) The blood supply of the femoral shaft. J Bone Joint Surg [Br] 35: 462-466
12. Laing PG (1960) The blood supply of the bones of the forearm and hand. Surg Clin North Am 40: 311-320
13. Longia GS, Ajmani ML, Saxena SK, Thomas RJ (1980) Study of the diaphyseal nutrient foramina in human long bones. Acta Anat 107: 399-406
14. Loreti F (1955) Note anatomiche sulle fonti arteriose e sullarchitettura della "rete articulare cubiti" (Henle) nell'Uomo. Min Chir 10: 1123-1126
15. MacNab I, de Haas WG (1974) The role of the periosteal blood supply in the healing of fractures of the tibia. Clin Orthop 105: 27-34
16. Menck J, Schreiber HW, Hertz T, Bürgel N (1994) Angioarchitektur von Ulna und Radius und ihre praktische Relevanz. Langenbecks Arch Chir 379: 70-75
17. Mysorekar VR (1967) Diaphyseal nutrient foramina in human long bones. J Anat 101: 813-822
18. Nelson GE, Kelly PJ, Peterson LFA, Janes JM (1960) Blood supply of the human tibia. J Bone Joint Surg [Am] 42-A: 625-635
19. Nutz V, Heitmann HD (1989) Einfluß von Operationszeitpunkt und Durchblutungswertigkeit verschiedener Femurabschnitte auf die Frakturheilung. Langenbecks Arch Chir 374: 340-348
20. Pagliei A, Brunelli F, Gilbert A (1981) Anterior interosseous artery: anatomic bases of pedicled bone grafts. Surg Radiol Anat 13: 152-154
21. Penteado CV, Masquelet AC, Romana MC, Chevrel JP (1990) Periostal flaps: anatomic bases of sites of elevation. Surg Radiol Anat 12: 3-7
22. Phemister DB (1940) Changes in bones and joints resulting from interruption of circulation. Arch Surg 41: 436-472
23. Rhinelander FW (1968) The normal microcirculation of diaphyseal cortex and its response to fracture. J Bone Joints Surg [Am] 50-A: 784-800
24. Shulman SS (1959) Observations on the nutrient foramina of the human radius and ulna. Anat Rec 134: 685-697
25. Teot L, Gilbert A, Amichot G, Bernière J, Pous JG, Carlioz H, (1984) Vascularisation des épiphyses en croissance: le membre supérieur. Ann Chir Main 3: 237-244
26. Trueta J, Caladias AX (1964) A study of the blood supply of the long bones. Surg Gynecol Obstet 118: 485-498

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Otorom 1

Otorom 1 forms part of the current expansion in educational CD-ROMs.

Initial reactions :

* technical aspect: it is simple to use and there are no special problems in installation. There is manifestly some difficulty between the words and their context. The management of the characters used was not that originally foreseen and despite some attempts to change it, it has never been possible to use good characters, which gives rise to imperfections in pre-sentation. However, this risk is mentioned in the brief documentation and simple technical solutions exist.

* ergonomic aspects: the ability to roam among the various topics is very satisfying. Reading of the texts in the form of scrolling menus is a little tedious. However, there is a great lack of functionality in this approach to interactivity, that of thehypertext, a basically important feature in interactive CD-ROMs. It was not possible to quit the CD-ROM without waiting for the complete scrolling of the "end credits", with animated photos of the coauthors. The user may find this tedious when, repeat-ing his study, he encounters this final sequence for the nth time. It has to be said that he has already benefited from a long initial presentation without the famous little box: "do not display this screen subsequently", which is found in quite a number of commercial products.

* as regards content, there are several levels of reading:

- for students: this CD-ROM seems very didactic and quite adequate, for instance in the surgery of vertigo. Evidently this tool is well-suited to supervised instruction. There is no excess of information. The planned presentation is effective for synthesis of information. In this context, the presence of little tests is completely appropriate. In this option, this support seems very useful; the question under study can be introduced or concluded by the use of this CD. This may become the university teaching of the future. But actually, more is required of it; in view of the quality of the photographic documents it may well be felt that the video presentations should last longer. In fact, they are very short, of the order of a few seconds.

- As regards wider knowledge, this "lapidary", summarised, synthetic aspect leads to much frustration: one would like to know, on the one hand, the choices advocated by other teams of authors and, on the other, the arguments in favor of certain options. One would like more discussion; as it is, only one solution is recommended. Is this a good or a bad one? The answer to this question doubtless depends on the level of competence. Lastly, a single CD-ROM canot replace every otologic publication

- To sum up, as regards its content this CD-ROM is sufficiently useful to provoke a sense of something lacking in its content; CDs should be made at different levels, without dealing with so many subjects on the same CD. As the title is OTO ROM1, it may be expected that there will be a series.

Altogether, in view of the mediocre quality of some currently published CDs, a lack of value might have been feared, but this is not the case. After this initial CD we await the series, possibly by authors of different experience, which would advantageously introduce discussion. We may also expect a better balance between form and content: exploitation of the performance of the multimedia support currently available, and greater reliance on interactivity to construct a real training document and not just the introduction or conclusion to a subject. Such a development is essential in view of the competition that is already manifest.

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