THE VASCULAR PATTERN OF THE ANTERIOR MUSCLES OF THE FOREARM IN ADULTS IN RELATION TO VOLKMANN'S ISCHAEMIC CONTRACTURE

V. BONI,* M.D.(Bologna)

From the Nuffield Orthopaedic Centre, Oxford

There exists already a copious literature on the blood supply of various organs and tissues, yet only a few papers are dedicated to the description of vascular patterns in human skeletal muscles.

Wollenberg¹² and Campbell and Pennefather⁵ drew attention to the lack of anastomoses between adjacent muscle groups in the lower limbs, and they stressed the fact that certain muscles were penetrated by a number of vessels, whereas others received their supply from a single artery.

Blomfield¹ recognized five main types of vessel distribution in muscles of the lower extremities of man. He related the vulnerability or otherwise of some muscles to ischaemia to several vascular factors, among them the number of nutrient arteries derived from independent sources and the particular intramuscular arrangement, the longitudinal disposition being more susceptible to injury than the pattern of anastomotic loops.

Edwards⁷ classified the muscles of the lower limbs of man into: (a) Those receiving vessels from several sources; (b) those possessing a series of arteries arising from a long segment of one major trunk; (c) those supplied by one or by only a few branches, taking origin from a localized segment of one arterial trunk. In explaining the liability of particular muscles to ischaemia, he insisted that the circulation in a muscle is an isolated unit, the arteries having no substantial connections with the vessels of the neighbouring structures. An intramuscular network of anastomoses between branches of the arteries does exist, but as Le Gros Clark and Blomfield⁸ have shown, it is often of a pattern which does not prevent ischaemia after occlusion.

Brash³ claimed that in most of the muscles there are subsidiary arteries, usually placed at

their periphery, close to bony attachments or tendinous endings; much variation in this auxiliary blood supply is, however, present.

Salmon¹⁰ contrasted the arrangements of arterial blood supply of the flexor muscles of the forearm with those of the extensor group. He noted a more abundant supply of vessels in the flexor groups and he emphasized their greater liability to vascular injury.

It would appear from a review of the literature that more attention should be focussed on the intramuscular vascular patterns of those muscles which, like some in the forearm, are prone to be affected by Volkmann's paralysis.

The purpose of the present paper is to describe the vascular anatomy of each of the muscles of the anterior compartment of the forearm, and to discuss the possible implication of these anatomical findings in explaining the pathogenesis of the ischaemic contracture known as Volkmann's paralysis.

Materials and Methods

Fourteen forearms of adult cadavers have been studied after intra-arterial injection. The investigation was confined to the muscles of the anterior aspect of the forearm.

Micropaque, a 10% barium sulphate suspension alone or mixed with carmine red (2% or 4%) was injected under a constant pressure of 140 mm. Hg through a fine polythene cannula (3 mm. diameter) into the distal end of the brachial artery.

The muscles were dissected out individually after fixation of the whole forearm in neutral formalin. Each muscle was carefully dissected under water, so that the perimysium could be completely removed. The specimens were then X-rayed, using fine-grain films. The general pattern of vessel distribution was further studied in specimens cleared by the Spalteholz technique.

* Dr. Vittorio Boni, Istituto Ortopedico Toscano, 'P. Palagi,' Viale Michelangelo 41-47, Florence, Italy.

Some of the specimens of whole muscles were cut transversely into three or four segments and these also were radiographed. In this way more detailed pictures of the intramuscular anastomoses were obtained.

The arterial patterns are described below. A few minor variations were noted in some specimens and these will be mentioned.

The Arterial Vascularization of the Muscles of the Anterior Compartment of the Forearm

Brachioradialis.—In all the specimens examined this muscle had a very distinctive vessel pattern. Where the radial artery was related to its deep surface in the forearm, a single nutrient artery entered it. From this long vessel a succession of branches arose which entered the muscle proper. Each of these penetrated it as a relatively large trunk, crossing the muscle belly obliquely, adjacent nutrient stems running roughly parallel to each other (Fig. 1). These arborized into a mass of fine anastomosing channels which were particularly profuse in the proximal and central segments of the muscle (Fig. 2). There were no vessels found entering the muscle from its superficial aspect, except in one case, when a few fine arteries passed into the anterior surface of the lower third of the muscle. These were derived from arteries coursing in the perineurium of the radial nerve.

Flexor carpi radialis.—The vascularization sprang from the radial artery, through a single vessel shown traversing the length of this muscle. From this, short branches came off at right angles in every case examined. These branches passed into the muscle belly and subdivided regularly. Successive divisions, arising from the first generation of branches of the main intramuscular arteries, tended to align themselves longitudinally along the muscle belly. The anastomosis so formed did not appear as closely woven as it was in the case of the brachioradialis.

Pronator teres.—The fleshy mass of this muscle was completely filled by a delicate network of fine vessels, which arose from an isolated trunk running along the lateral length of the muscle. Branches arising from the nutrient artery in regular sequence arborized at once within the muscle mass. In only one case, the pronator teres was found supplied by three different nutrient vessels, respectively at its upper, middle and lower third, but these arose from a single trunk.

Flexor carpi ulnaris.—This muscle was supplied by about four or five main vessels entering the radial aspect of the deep surface of the muscle. An irregular pattern of arborization provided a free anastomosis within the muscle. There

FIG. 1.

were no connections between these vessels and those of the structures outside this muscle.

Palmaris longus.—This muscle was supplied through its deep surface by many different nutrient arteries, every one of which divided

FIG. 2.

into a superior and inferior branch. The intramuscular pattern resembled that seen in the pronator teres.

Flexor digitorum sublimis.—It possessed two sources of blood supply. One (radial part) gave rise to many branches, arising at regular intervals, which arborized at once within the muscle belly (Fig. 3 (a)). The other source (ulnar part) was represented by a long artery, which supplied the inferior half of the muscle (Fig. 3 (b)). This artery coursed between the two flexor muscles, and sent many branches to the flexor digitorum profundus. The intramuscular pattern showed a free anastomosis between the branches of these two different systems of supply.

Flexor digitorum profundus.—This was supplied on its anterior surface by several branches arising from a long artery, which ran between this muscle and the flexor digitorum sublimis, to which it also sent some branches (Fig. 4). The anterior interosseous artery supplied the deep surface of this muscle, running completely along its whole length between this muscle and the interosseous membrane. The number of its large arteries of supply varied between six and ten. Half of them ran into the outer side, half to the inner side. Many other smaller vessels were occasionally found crossing the interosseous membrane and piercing the deep surface of this muscle in its upper two-thirds. Every vessel ended in thick retiform knots, for the most part within the central and medial part of the muscle, anastomosing freely with their neighbours. From these

vessels branches also passed into the periosteum of the forearm bones.

Flexor pollicis longus.—This muscle was found to receive many branches from several sources. The penetrating vessels ended in a delicate network within the muscle.

Discussion

To summarize this study, the anterior muscles of the forearm in the adult may be grouped into three main types according to their vascularization:

Type 1: Muscles which receive their blood from more than two vascular sources (flexor carpi ulnaris, palmaris longus, flexor pollicis longus).

Type 2: Muscles which receive their blood supply from only two different arterial sources (flexor digitorum sublimis, flexor digitorum profundus).

Type 3: Muscles which receive vessels from a single longitudinally placed artery (brachioradialis, flexor carpi radialis, pronator teres).

A knowledge of these facts may be of some importance in interpreting the pathogenesis of Volkmann's paralysis.

Correlating these findings with a clinical study on Volkmann's contracture,¹¹ it appears that the muscles which receive their blood supply from only one or two arteries are more susceptible to fibrous ischaemic contracture than the others.

These arteries may be constricted, either at the level of their hila, as a result of rising inter-fascicular pressure by oedema confined to the muscle, or throughout their longitudinal course

FIG. 3.

as a result of a general increase in transmural pressure from without. In this aspect it must not be forgotten that the anterior antebrachial region is an inextensible anatomical compartment, limited behind by the radius and ulna and the tense interosseous membrane, and in front by a well-defined

fascial sheath. This large anterior compartment is divided into many smaller cylindroid sections by fascial planes which restrict greatly the area of tissue fluid diffusion.

In each of the muscles we have studied the capillary vessels form close-mesh plexuses, pre-

FIG. 4.

dominantly located in the proximal and central sections of the muscles. This particular distribution may explain why the pathological changes are confined exclusively to these areas.

Summary

The arterial supply of the muscles of the anterior compartment of adult forearms has been studied by dissection and microradiography of injected specimens obtained at post-mortem.

The observation by previous authors that the arterial supply of each muscle is independent and distinct from that of neighbouring structures is confirmed.

The relationship between the vascular pattern of muscles and their vulnerability to ischaemia is considered.

Acknowledgments

I wish to thank Professor J. Trueta for his advice during this work, and also Mr. H. V. Crock for his help in obtaining the specimens. My thanks are also due to Miss M. Litchfield for help in preparing the material for examination and to Mr. Charles for preparing the microradiographs.

REFERENCES

1. BLOMFIELD, L. (1944-45), *Proc. roy. Soc. Med.*, **38**, 617.
2. BOWDEN, R. E. M., and GUTMANN, E. (1949), *J. Bone Jt. Surg.*, **31b**, 356.
3. BRASH, J. C. (1955), 'Neuro-vascular Hila of Limb Muscles.' Edinburgh and London: E. & S. Livingstone Ltd.
4. BROCKIS, J. G. (1953), *J. Bone Jt. Surg.*, **35b**, 131.
5. CAMPBELL, J., and PENNEFATHER, C. M. (1919), *Lancet*, **i**, 294.
6. DIBLE, J. H. (1957), *Schweiz. med. Wschr.*, **87**, 1161.
7. EDWARDS, E. A. (1953), *Surg. Gynec. Obstet.*, **97**, 87.
8. LE GROS CLARK, W. E., and BLOMFIELD, L. B. (1947), *J. Anat. (Lond.)*, **79**, 15.
9. McCORMACK, L. J., CAULDWELL, E. W., and ANSON, B. J. (1953), *Surg. Gynec. Obstet.*, **96**, 43.
10. SALMON, M. (1957), *Rev. Chir. Orth.*, **43**, 3.
11. SCAGLIETTI, M. (1957), *Arch. Putti Chir. Organi Mov.*, **8**, 60.
12. WOLLENBERG, G. A. (1905), *Z. orthop. Chir.*, **14**, 312.

RUTHIN CASTLE, NORTH WALES

A Clinic for the diagnosis and treatment of Internal Diseases (except Mental or Infectious Diseases). The Clinic is provided with a staff of doctors, nurses, technicians, modern Radiological and Physiotherapy departments.

The surroundings are beautiful. The climate is mild. There is central heating throughout. The annual rainfall is 30.5 inches, that is less than the average for England.

The Fees are inclusive and vary according to the room occupied.

For particulars apply to THE SECRETARY, Ruthin Castle, North Wales.

Telegrams: Castle, Ruthin.

Telephone: Ruthin 66