BLOOD VASCULAR PATTERN TO AND THROUGH THE GASTROCNEMIUS OF THE SEDENTARY MALE RAT

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ABSTRACT

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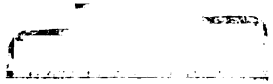
Twenty-four male, post-puberty rats (Sprague-Dawley) were placed in individual sedentary cages. The rats were divided into three groups, which were injected under regulated temperature and pressure at the aorta just above the bifurcation with either latex, india ink or vinyl acetate. Analysis of the various injectional media for the purposes of gross and intramuscular arterial determinations were performed and the blood vascular pattern was identified via dissection and microphotography.

A 50% latex ammonium solution was found to be superior for dissection purposes. The intramuscular arterial pattern, although variable, can be reduced to a generalized architecture common to most sedentary rats.



BLOOD VASCULAR PATTERN TO AND THROUGH THE GASTROCNEMIUS OF THE SEDENTARY MALE RAT

By

Barry S. Brown

A THESIS

Submitted to
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Dedicated

to

my wife

and

forthcoming child

ACKNOWLEDGMENTS

I wish to acknowledge Dr. Wayne Van Huss, my major advisor, and Dr. Rexford Carrow, Assistant Professor in the Anatomy Department, for the assistance and encouragement they have given me during my plight. Additional expression of gratitude is extended to Mrs. Geraldine Wilson, Mr. Robert Ruhling, and Mr. Carl Oehling for their valuable assistance during the injectional phase of the experiment.

The principles of equality of opportunity and dedication to one's work fostered by my parents and brother have contributed in great measure to the final outcome of this thesis.

FOREWORD

The format of this thesis differs somewhat from the conventional four or five chapter approach used so frequently. It has been mutually decided by Dr. Van Huss and myself to present the material in the same manner as it was submitted for publication. I am of the opinion greater benefit will be derived by presenting this thesis in publication form, being that it represents a more realistic approach to the presentation of scientific research.

Within the framework of the thesis will be found scattered reviews of pertinent literature as they relate to the topic being discussed.

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INTRODUCTION

Research involving the gastrocnemius of the rat (Carrow et al., 1967; Delasante, 1964) has been undertaken without regard to the major blood vascular pattern within the muscle. The gross arterial supply may represent an essential factor in determining capillary to fiber ratios (Krogh, 1919; Paff, 1930, Carrow et al., 1967) as well as being of interest in ligation studies.

A survey of literature both past and present indicates the classification of muscle according to its blood supply into three main classes. Both the medial and lateral heads of the gastrocnemius have been reported (Campbell, 1919) to receive their blood supply from one source with little potential for collateral channels. With respect to the rat, one author (Jaya, 1958) classifies a "spindle shaped muscle" as having a "dense basket type" of circulatory pattern, this being most indicative of the gastrocnemius.

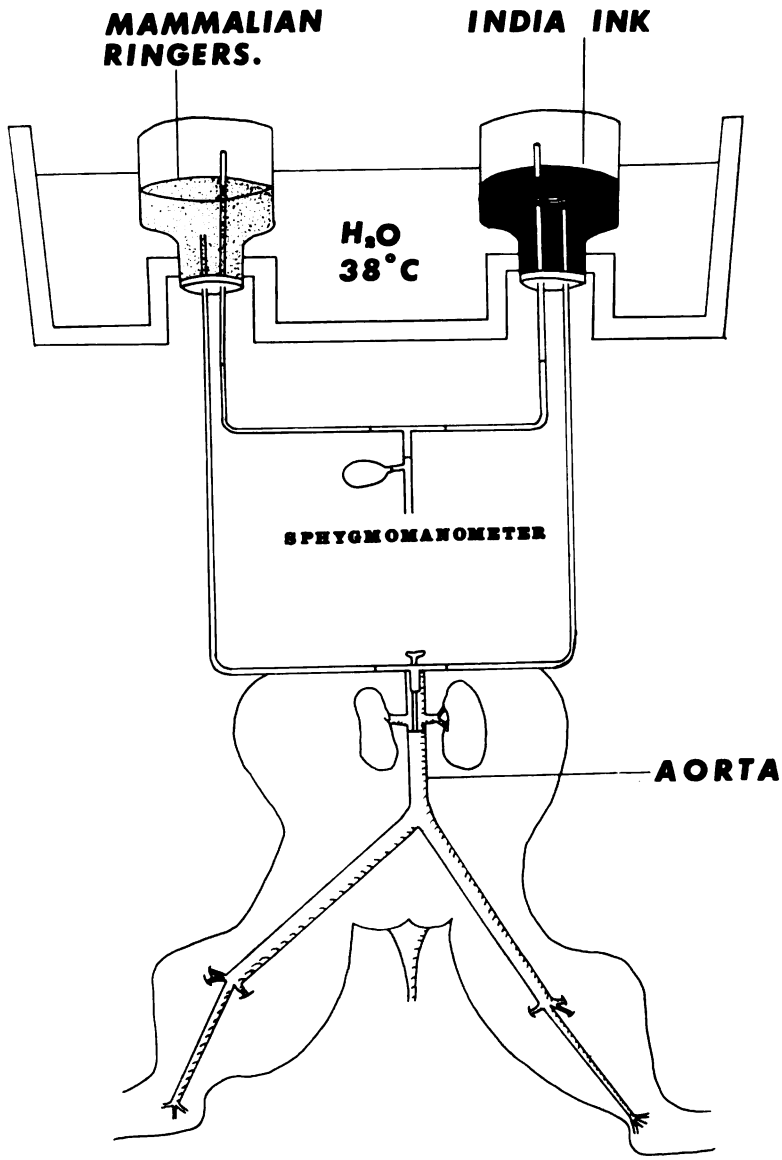
Aside from the abovementioned references, only one atlas (Greene, 1959) contains the major arterial supply to the gastrocnemius of the white albino rat with any degree of accuracy. To my knowledge, our endeavor to map out the intramuscular pattern to the gastrocnemius of the sedentary male rat represents an initial exploration in this area.

METHOD

Twenty-four male albino rats (Sprague-Dawley) were placed in sedentary individual cages until they had attained an age of 120 days. Four rats per day, over a total of six days were administered a dosage of 60 mg/kg of sodium pentobarbital intraperitoneally. The observed variability of onset of general anesthesia can be explained by the differing rates of drug metabolism by the rats' liver. No further anesthetic was required either before or during surgery to maintain a surgical level of anesthesia. Pentobarbital was chosen in deference to ether due to its ability to maintain a constant level of anesthesia without the need for an anesthetist, in addition to the reports (Olmstead and Page, 1966) of no significant change in mean arterial pressure that might tend to bias the arterial pattern.

The equipment utilized in the perfusion and injection technique is illustrated in Figure 1. Although of a make-shift variety, the apparatus proved to be experimentally sound and extremely inexpensive. Allowing for a ten-minute cardiovascular period of adjustment following anesthesia, a laparotomy was performed. The aorta was carefully isolated from the exit of the superior mesenteric artery to the bifurcation of the common iliac arteries.

Figure 1.--Injection apparatus.


MAMMALIAN RINGERS.
INDIA INK
H_2O
38°C
SPHYGMOMANOMETER
AORTA

A polyethylene tube (P.E. = 20) fastened around a 20 gauge 1½ inch disposable needle was inserted into the aorta, one-half inch caudal to the right renal artery and secured with non-absorbable silk suture.

Two animals were used for the injection of vinyl acetate in an attempt to produce a corrosion specimen (Ward's Service Bulletin, No. 5). Acetone was used in place of Mammalian Ringer's solution to prevent the coagulation of vinyl acetate which would occur with water.

Eight animals were injected with india ink and fourteen with latex as outlined below.

The hindlimbs were exsanguinated with Mammalian Ringer's solution at 38°C. When the fluid issuing forth from the cut Inferior Vena Cava appeared clear, the perfusate (india ink, latex or vinyl acetate) was introduced by the turning of a valve. Heparin (1 cc/liter) was added to prevent clotting. India ink and latex were allowed to run two minutes, whereas, the vinyl acetate perfused the lower limb for two hours to assure entrance of the plastic into the arterioles. All three injection media were perfused at a pressure of 120 mmHg commensurate with the normal blood pressure of the rat (Durant, 1927).

Following the injection, the skin and overlying muscle (Semimembranosus and Biceps Femoris) was removed and a sketch of the major arterial pattern to the gastrocnemius was recorded. The right and left limbs

were then removed at the acetabulofemoral joint and treating according to the perfusage used as follows:

The muscle of the arteries injected with vinyl acetate were severed at the achillis tendon, tied to a ten-gram weight and suspended in papain.

The india ink specimens were fixed in 10% formalin for 24-48 hours, dehydrated in three changes of acetone (30 minutes each), and cleared in methyl benzoate.

The latex injected artieries were fixed in 10% formalin and remained there until dissected.

Microphotographs of the dissected specimens were taken with a 35mm camera attached to a Leitz Ortholux microscope magnified 25 times.

Presentation of the arterial pattern from diagrams instead of micrographs was arrived at by personal consultation with Alfred M. Lucas (Research Zoologist and Project Leader, USDA Avian Anatomy Project). The sacrifice of realism for diagrammatism appears to be supportable on the grounds of presenting a clearer, understandable analysis of an otherwise confusing, non-informative pattern.

OBSERVATIONS

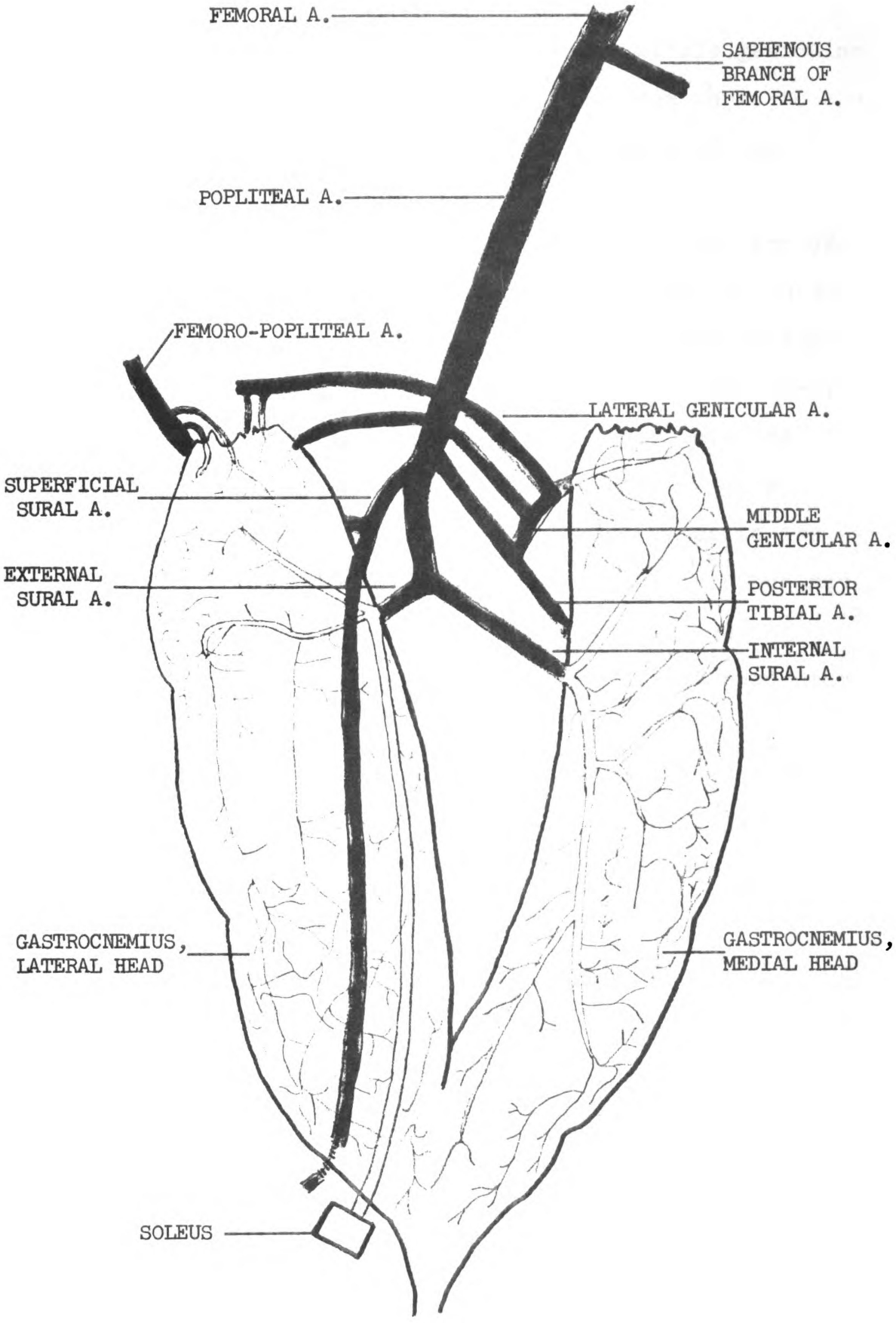
The diagrammatic illustrations represent generalized vascular patterns to be found in sedentary male albino rats.

According to Campbell and Pennefather (1919), the human gastrocnemius has been classified into the third main class with respect to its blood supply. The vascular bed is derived exclusively from one source with almost total absence of potential collateral channels (Campbell et al., 1919). Abramson (1962) adds that the variability of arterial architecture found within muscles is dependent upon the availability of alternate arterial sources. It might then be argued that there is little variability found in vascular patterns of muscles supplied from a single source. Campbell et al. (1919) would include the human gastrocnemius in this category, but does not generalize beyond this species.

Gross Supply

This author agrees with the generalization that the bulk of the vascular supply to the medial and lateral heads of the gastrocnemius stems from the internal and external sural aa., respectively (see Figure 2). There appears to be, however, the presence of one additional

Figure 2.--Gross arterial supply to the gastrocnemius. Axillary view. Left leg. Diagrammatic.


FEMORAL A.
SAPHENOUS BRANCH OF FEMORAL A.
POPLITEAL A.
FEMORO-POPLITEAL A.
LATERAL GENICULAR A.
SUPERFICIAL SURAL A.
MIDDLE GENICULAR A.
EXTERNAL SURAL A.
POSTERIOR TIBIAL A.
INTERNAL SURAL A.
GASTROCNEMIUS, LATERAL HEAD
GASTROCNEMIUS, MEDIAL HEAD
SOLEUS

branch to the medial head arising from the middle genicular artery as supported by Greene (1959), and from three to six additional vessels to the lateral head arising in the following manner:

A variable distance cephalad to the bifurcation of the popliteal artery into the external and internal sural aa., a medial (posterior tibial) and lateral (superficial sural) branch diverge at acute angles to the parent stem. Before the posterior tibial artery dips underneath the medial head, the middle genicular artery emerges at a right angle and passes to the gastrocnemius close to its point of attachment to the femur. One of two branches may spring forth from the middle genicular artery, passing directly or sending side branches to the lateral head near its point of attachment to the femur.

The superficial sural artery, having emerged from the popliteal artery, continues down the lateral head of the muscle, parallel to its longitudinal axis along the dorsal border. A variable distance from its exit a recurrent branch, the femoro-popliteal artery, is given off at right angles, and travels along the upper border of the lateral head to supply the biceps femoris muscle. As it passes the point of attachment two small branches may emerge and pass to the lateral head near the femur. Toward the caudal end of the lateral head, a small branch from the superficial sural has been constantly observed

to penetrate the muscle substance and begin its intramuscular design.

Intramuscular Design

This author did not observe the numerous arterial anastomoses of the primary intramuscular vessels as described by Krogh (1936). As can be demonstrated in Figure 3, three main intramuscular arteries usually arise from the external sural, and two major arteries from the internal sural artery. Each of the arteries immediately diverge upon entering the muscle substance and travel to their respective areas outlined in Figure 3. On the basis of its major* intramuscular supply, the lateral head can be divided into upper, middle and lower portions as there is little overlap of the basic pattern. The medial head may be divided, using the same criteria, into an upper portion comprising approximately one third of the total area, and a lower portion making up the remainder (see Figure 4).

A constant vessel arises from the superficial sural artery approximately three-quarters of the distance from its exit off the popliteal artery and supplies the lower lateral quadrant of the lateral head.

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*The major intramuscular arteries were designated as those vessels maintaining a diameter between .15 and .32mm (or one to two units as observed at 25 magnification on the Leitz microscope).

Figure 3.--Major intramuscular arterial pattern to the gastrocnemius. Arterial diameter range: .15-.32mm. Axillary view. Left leg. Diagrammatic.

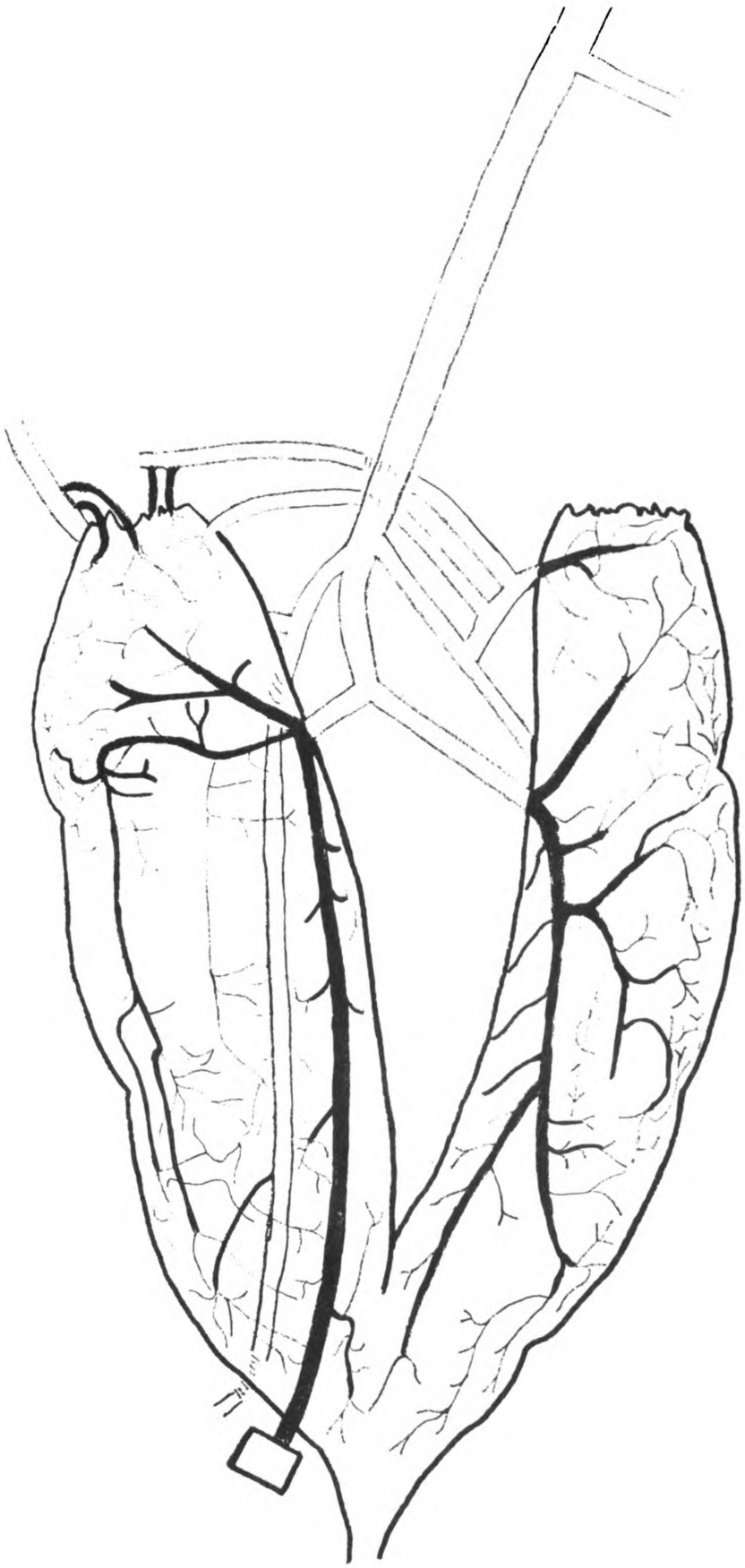

Figure 4.--Minor intramuscular arterial supply. Arterial diameter range: Less than .15mm. Axillary view. Left leg. Diagrammatic.

The cephalic ends of both heads are supplied by the branches of the genicular arteries and occasionally by the recurrent vessels of the femoro-popliteal artery. Having seen no reference in the literature to these recurrent vessels, it may well be appropriate to designate these branches as the "recurrent femoro-popliteal aa."

There is a lack of certainty concerning the level to which the dissection was performed. On the basis of size, vessels were dissected with a diameter of less than 150 u, therby, categorizing them as arterioles. Yet one author (Wiedeman, 1962, 1965) disclaims the defining of an arteriole on the basis of its diameter. It is my subjective opinion that insufficient branching had taken place to reach arteriole level and that arteriolar size studies should be undertaken to establish norms.

Figure 5.--Major intramuscular arterial supply of the medial head of the gastrocnemius. X 25.

DISCUSSION

The clinical importance of the gross arterial pattern has been mentioned (Le Gros Clark and Blomfoeld, 1945; Abramson, 1962) as being of surgical significance in the prevention of anaerobic infection as well as muscle degeneration.

Studies on the presence of arterial anastomoses and the effects of devascularization of muscle as suggested by Le Gros Clark et al. (1945) may shed credibility to the claim that the gastrocnemius is liable to the development of necrosis (Pearson, 1965).

It is the author's expectation that greater emphasis be drawn to the effects of pathology and physical stress upon the blood vascular pattern to and within skeletal muscle.

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