Digital Arteriography in Occlusive Arterial Disease and Clubbing of the Fingers

By TIMOTHY TAKARO, M.D., AND EDGAR A. HINES, JR., M.D.

SUMMARY
A study of transbrachial digital arteriography led to the development of a technique that includes the use of an intra-arterial vasodilator (tolazoline) measurement of circulation time, direct roentgenographic magnification and serial exposures of long (14 by 35-inch) films in cassettes. This technique permitted study of the fine details of digital arteriograms of 34 patients with clubbing of the fingers or peripheral occlusive arterial disease. The ulnar artery was nonopacified in 13 cases and segmental areas of nonopacification of digital arteries were seen in 17 of the entire group, in many instances in the absence of symptoms of occlusive arterial disease. The technique is recommended for more adequate study of the peripheral microangiopathies.

TO MAKE possible detailed study of the digital arteries of the hand and their branches in patients and to highlight this detail, a technique of arteriography was developed and applied in a series of 34 patients. The technique includes the use of percutaneous puncture of the brachial artery, the intra-arterial administration of a vasodilator drug, measurement of the circulation time from the antecubital fossa to the hand, and direct roentgenographic magnification to twice normal size. A special cassette changer for long (14 by 35-inch) cassettes is used. This report describes the technique and the results obtained in this group of 34 patients.

Technique
The patient, who has been premedicated, is placed on an elevated radiolucent table top with the arm to be examined stretched out on a thin radiolucent arm board of wood, free of knots and artifacts and supported at both ends independent of the cassette changer (in order to eliminate vibrations from changer). Elevation of the patient is such that the outstretched hand and forearm are at a 20-inch distance from the cassette changer,* and the x-ray tube† at 40 inches to give magnification to two times normal size. This general arrangement has been previously described.2 To minimize motion, the patient’s hand and each of the fingers are taped singly to the board with radiolucent tape with the palm either up or down. Test films are exposed at 40 to 44 kv, 20 ma, 0.5 second, for position and technique. A brachial arterial puncture is done and a needle is inserted upstream. The needle‡ is passed 2 to 3 cm up the lumen of the brachial artery with the aid of a smoothly rounded, closely fitting blunt stylet which protrudes several millimeters beyond the point of the needle. A short piece of plastic tubing is attached to the needle and taped to the forearm. Tolazoline (Priscoline), 50 mg in 10 ml of physiological saline, is injected slowly to minimize arterial spasm due to the needle puncture. A scintillation counter§ attached to a recorder** is positioned over the hand, and 40 microcuries of RISA (radioactive iodinated serum albumin), in a 2-ml volume is placed carefully in the plastic tubing. On signal, using

†Machlett double focus rotating anode x-ray tube, using 0.3-mm focal spot.
‡18-T arterial needle, Becton-Dickinson, Englewood, New Jersey.
§One-inch scintillation detector, Nuclear, Chicago, Illinois.
**Nuclear, Chicago, Illinois.

From the Veterans Administration Hospital, Oteen, North Carolina.
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10 ml of saline as a driving force, it is suddenly injected as a bolus into the brachial artery, while the recorder is turned on. The time from injection to peak of curve of the recording is taken to indicate the approximate circulation time from distal brachial to digital arteries. This information is used to time the subsequent film sequence after injection of contrast medium. After warning the patient to avoid the slightest motion of the hand or fingers, in spite of the expected hot or burning sensation, 25 to 30 ml of contrast medium, which may include 5 to 10 ml of the patient's own blood freshly drawn into the syringe, is injected rapidly by hand. Filming is begun at a time, following the injection, that is based on the previously determined circulation time in the arm. The cassettes are changed as rapidly as the mechanism will allow, which is about every 2 seconds. A long cassette (14 by 35-inches) is used in which two 14 by 17-inch films have been placed. The procedure may be repeated if the films are unsatisfactory. An electrocardiograph attached to the x-ray control box records the exact time of each of the six exposures.8

Results

In three angiograms, excessive motion blurred detail. In the remainder, careful assessment of the arteries of the distal forearm, wrist, both palmar arches, the digital arteries, and their finest ramifications in the tips of the fingers was usually possible, at a magnitude of twice normal size. Usually the veins were also opacified.

Twelve patients with a clinical diagnosis of occlusive arterial disease of the hand were subjected to arteriography to confirm the diagnosis and determine the extent of the occlusions. Of these, the ulnar artery in the forearm or at the wrist was not opacified and was presumed to be occluded in five, and the radial artery in one. A median artery (located where one might expect the interosseous artery) was present in one patient in whom no ulnar arterial opacification was present.4 Multiple, often segmental, digital arterial occlusions involving at least two of the patients' fingers were seen in 10 of 12 patients with the clinical diagnosis of occlusive arterial disease of the hand (table 1). In the one patient without these findings, spasm of all digital arteries was observed in spite of the prior administration of Priscoline. Nonopacified segments were most commonly seen in the index finger (eight of the 12 patients), middle finger (six of the 12), and fifth finger (five of the 12). In one patient with scleroderma, occlusive segments were noted in arteries of all five digits (fig. 1).

Nineteen patients with evidence of clubbing of the fingers were also studied. They were informed that the angiogram was not necessary for diagnosis or treatment but might aid in understanding the condition, and was a safe procedure. All patients assented readily to arteriography. In at least two of these patients, clubbing had been noted since early childhood, had occurred also in a parent, and was not associated with cardiopulmonary disease. These were felt to be on an hereditary basis. In eight of the 19 patients, the ulnar artery in the forearm or at the wrist was nonopacified or displaced from its usual location to an interosseous position or replaced by a large radial arterial branch (table 2). The radial artery was occluded in one. In one patient, three large arteries were observed, which were located in the position ordinarily occupied by the radial artery. Digital arterial occlusive segments were present in six patients; in four of these patients more than one finger was involved. Hypervascularity of the terminal tufts, as judged by an increase in the number and size of the most distal ramifications of the digital arteries or vascular formations like arteriovenous communications, or both, were noted in 13 of these 19 patients. In some, it was marked (fig. 2). This change was observed in only one patient in the group with a clinical diagnosis of occlusive arterial disease of the hand. The terminal phalanges of one patient's fingers had a bifid appearance, which was thought to be on a congenital basis, and clear-cut terminal bony proliferations were observed in nine patients. In contrast, such bone changes could be seen in only two

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8Methylglucamine diatrizoate (Renografin 60%), sodium diatrizoate (Hypaque 50%), sodium iothalamate (Conray-400 and Angio-Conray) were all used with satisfactory results.

Circulation, Volume XXXV, April 1967
Table 1

Arteriographic Findings in Twelve Patients with Occlusive Arterial Disease

<table>
<thead>
<tr>
<th>Patient</th>
<th>Clinical diagnosis</th>
<th>Occlusions Radial artery</th>
<th>Occlusions Ulnar artery</th>
<th>Digital arterial occlusions by digits</th>
<th>Hypervascularity of fingertips</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Occlusive arterial disease of hand</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
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<td>TAO</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
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<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>4</td>
<td>TAO</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>TAO</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
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<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>7</td>
<td>Raynaud's phenomenon</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>8</td>
<td>Raynaud's phenomenon</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>9</td>
<td>Scleroderma</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<td>10</td>
<td>Occlusive arterial disease of hand</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>11</td>
<td>Occlusive arterial disease: injury(?)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>12</td>
<td>Raynaud's phenomenon</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

TAO = thromboangiitis obliterans; + = occluded, either segmentally or completely.

Table 2

Arteriographic Findings in Nineteen Patients with Clubbing of the Fingers

<table>
<thead>
<tr>
<th>Patient</th>
<th>Clinical diagnosis</th>
<th>Occlusions Radial artery</th>
<th>Occlusions Ulnar artery</th>
<th>Digital arterial occlusions by digits</th>
<th>Hypervascularity of fingertips</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pulmonary fibrosis</td>
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<td>+</td>
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</tr>
<tr>
<td>2</td>
<td>Pulmonary tuberculosis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>3</td>
<td>Syphilis</td>
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<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>Pulmonary tuberculosis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>5</td>
<td>Pulmonary fibrosis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>Eisenmenger's disease</td>
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<td>+</td>
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<td>+</td>
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<td>7</td>
<td>Pulmonary fibrosis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>8</td>
<td>Pulmonary tuberculosis</td>
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<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>9</td>
<td>Emphysema</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>10</td>
<td>Carcinoma of lung, tuberculosis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>11</td>
<td>Bronchogenic cyst</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>12</td>
<td>Carcinoma of lung</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>13</td>
<td>Obstructive lung disease</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>14</td>
<td>Idiopathic hereditary clubbing of fingers</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>15</td>
<td>Carcinoma of lung</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>16</td>
<td>Pulmonary tuberculosis; idiopathic hereditary clubbing of fingers (?)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>17</td>
<td>Pulmonary tuberculosis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>18</td>
<td>Pulmonary tuberculosis</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>19</td>
<td>Idiopathic hereditary clubbing of fingers</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

+ = occluded, either segmentally or totally.
patients with the clinical diagnosis of occlusive arterial disease of the hand. One patient, without clubbing of the fingers, in whom the soft tissues of the fingers, hand, and forearm of the left upper extremity were markedly enlarged for at least 20 years, showed a bizarre proliferation of small arteries and veins in the forearm and hand. These were thought to represent congenital arteriovenous fistulae.

An attempt was made to analyze the anatomic variations of the superficial and deep palmar arches. There were many patterns in the configuration of these vessels, and in only eight of 34 patients were two clear-cut arterial arches observed. In 13 patients there was but one arch, and in five of these there was no visible ulnar artery. In five patients, a large branch of the radial artery supplied the ulnar digital vessels, and in two patients, no arterial arch could be identified.

The circulation time from the antecubital fossa to the palm of the hand, as measured by timing the appearance of peak radioactivity at the palm, after injection of radioactive iodinated serum albumin into the brachial artery, ranged from 4 to 13 seconds, with a mean of 5.2 seconds.

We were unable to establish a relationship between the velocity of the circulation (RISA circulation time) or skin temperature (monitored in many patients in a constant-temperature and constant-humidity room) with

\[ \text{Figure 1} \]

Distal portion of digital arteriogram of a patient with scleroderma, proven by autopsy, showing multiple digital arterial occlusions (small arrows). Collateral vessels are seen well on the medial aspect of the third digit (large arrow).
the appearance of the arteriograms or with the clinical diagnoses.

Two patients underwent a subsequent study. In one patient with occlusive arterial disease and a clinical diagnosis of thromboangiitis obliterans, digital arteriography was carried out before and several weeks after cervicothoracic sympathectomy. There was no appreciable difference in the appearance of the two angiograms. In another patient, with painful clubbing and bronchogenic carcinoma, angiography was done before and 6 weeks after pulmonary resection. Hypervascularity seemed to be less when the pain had disappeared after thoracotomy (figs. 3 and 4), although the RISA circulation time remained the same.

**Discussion**

This technique allowed detailed scrutiny of all the vessels from the distal forearm to the fingertips and was free of complications except for moderate to severe burning pain in the fingers, lasting a few seconds. We were surprised by the variation in patterns of opacification of the vessels at the wrist and palm. In the entire series, regardless of diagnosis, the ulnar artery was either nonopacified or misplaced frequently, and far more commonly (13 cases) than the radial (two cases). While nonopacification of ulnar arteries might be attributed in some instances to an unusual origin of the ulnar artery proximal to the point of puncture of the brachial artery, such anomalies are rare (less than 3% according
Digital arteriogram prior to surgery. Patient had bronchogenic carcinoma and painful clubbing of the fingers. Note hypervascularity of the terminal portions of the second, third, and fifth digits.

to McCormack and associates\textsuperscript{4} and would not provide a satisfactory explanation for such a high incidence, almost 40\%, in this study. However, anatomic studies of antebrachial,\textsuperscript{4} palmar, and digital\textsuperscript{5} arterial patterns confirm the frequency of deviations from the "normal" and emphasize the hazard of concluding that an occlusive lesion is present if the expected pattern is not seen.

The total number of documented digital arterial occlusions (17 of 34 cases), is also worth noting, and especially interesting was this finding in six patients with clubbing of the fingers.

It is apparent from other studies,\textsuperscript{6,7} as well as from ours, that several distinct types of clubbed fingers can be seen, apparently from different causes, and that not all clubbed fingers are associated with hypervascularity of the fingertips. Some, however, distinctly are. Our impression is that hereditary clubbing is painless with no increase in vascularity of the fingertips, while the clubbing associated with
intrathoracic disease can be painful and appears to be associated with hypervascularity. We had the opportunity of studying only one patient whose clubbing was associated with congenital cyanotic heart disease. On this patient’s arteriogram, multiple digital arterial occlusive lesions as well as hypervascularity of the fingertips were observed.

A number of good digital arteriographic studies on patients have appeared in the literature recently. In many of these studies digital arterial detail is not seen well. Among the best are those of Strickland and Urquhart and Laws and associates. Strickland and Urquhart reviewed the subject carefully in 1963, describing clearly the many anatomic variations of the arteries in the wrist and hand in 18 patients and depicting the fine ramifications of digital arteries. Law and associates’ report contains many detailed arteriograms, especially those of patients with rheumatoid arthritis. The extensive studies by Marshall and co-workers of 125 patients, most of them with arthritis, are helpful. Soila and associates focused on the problem of angiographic detail, using fine emulsions and photographic enlargement, rather than radiographic magnification.

It is apparent from these studies that many diseases can be associated with changes in the small blood vessels of the hands and fingers. These include nail dystrophy, rheumatoid arthritis, hypertrophic and gouty arthritis, Raynaud’s phenomena, thromboangiitis obliterans, clubbing of the fingers with or without pulmonary osteoarthropathy,
polyarteritis nodosa,9, 10 scleroderma,9 neoplasms, trauma (especially repetitive occupational trauma), ergotism,16 and arteriosclerotic aneurysms.17 In all of these, digital arteriography may be informative if there is adequate detail. In the enigma of clubbing of the fingers, angiographic study of the terminal vascular tufts of the fingertips, in conjunction with physiological and pharmacological studies might prove to be useful.18-23 DeTakats24 rightly pointed out the physiological and pathological importance of the "third force" or microcirculation which has long been ignored for lack of effective means of study in vivo. Our technique is presented, along with our initial results, as a method for improving angiographic detail of these fine vessels. Use of such specialized angiographic techniques and of currently available x-ray tubes of improved design, which make possible in vivo studies of the circulation with direct magnification,25 even up to 10 times,26 will undoubtedly lead to better results and to greater understanding of the microangiopathies involving not only the peripheral and more readily accessible areas of the body, but those of the internal organs as well.

References

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Circulation. 1967;35:682-689
doi: 10.1161/01.CIR.35.4.682
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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