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TOE BLOOD PRESSURE IN PERIPHERAL ARTERIAL DISEASE

Quantitative Evaluation of Occlusive Process Localized Mainly in the Arteries in Lower Leg and Foot

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In patients with obliterative arterial disease of the legs, the blood pressure distal to the occlusion is decreased, and measurement of the distal blood pressure yields information about the presence and the severity of the occlusive process. Various techniques are available. Calf plethysmography has been used in measuring the systolic blood pressure on the thigh (Dahn 1965 a, b). The Doppler shift ultrasonic detector allows measurement of the blood pressure as distal as on the ankle (Strandness et al. 1966, Carter 1969, Bollinger et al. 1970, Yao et al. 1969, Thulesius 1971) and by using a mercury in silastic strain gauge detector, Gundersen & Lassen (1970) and Carter & Lezack (1971) measured the blood pressure on the toes. The strain gauge technique has been used in this laboratory for some years and a multisegmental procedure as described by Gundersen (1972) and Bell et al. (1973) has been adopted.

In this communication the value of assessing a low toe blood pressure is demonstrated in patients where the occlusive process is localized so distally that the systolic blood pressure on more proximal levels, including the ankle, is normal or only slightly decreased.

METHOD

The systolic blood pressure was measured on the first toe, on the ankle, on the calf, and on the thigh. The method has been described in detail elsewhere (Gundersen 1972, Nielsen et al. 1972) and here only a brief description will be given:

A 24 mm wide cuff was fitted on the great toe. A commercially available mercury in silastic strain-gauge, balanced on a Wheatstone bridge as described by Hallböök et al. (1970) and connected to an ECG writer (Mingograph, Elema-Schönander, Sweden) was placed around the tip of the toe. The veins of the toe were emptied of blood by compressing manually the pulp of the toe, and the cuff was suddenly inflated to suprasystolic pressure level. The cuff pressure which was recorded on the writer was released at a rate of 1–2 mmHg per second and at a certain cuff pressure an increase of the tracing recorded, indicated that blood escaped under the cuff and filled the distal arterial tree. This pressure was taken to be the systolic blood pressure of the toe.

The procedure was carried out three times and at each measurement the brachial systolic blood pressure was measured by the standard auscultatory method. The mean of the distal pressure values and the mean of the systolic brachial pressures were calculated. In general the distal blood pressure was measured on both legs at the same time. Then the blood pressure was measured on the ankle level by using a 12 × 28 cm cuff, placed with the distal edge just above the malleoles. On the calf and on the thigh the systolic pressure was measured using a 18 × 60 cm cuff placed on the most voluminous part of the calf, and as proximal as possible on the thigh, respectively. For detection of volume expansion during ankle and calf pressure measurement, the toe-strain gauge was again used, whereas the measurement on the thigh was carried out with the detector, a long strain gauge, placed on the calf.

All measurements were performed with the patients in the supine position. The legs were carefully supported by sandbags and during the thigh measurements, a sandbag was also placed under the patients' knees to prevent the strain gauge on the calf from touching the couch. Room temperature was 26.0 ± 1° Celcius and skin temperature was 27.0–31.6° C as measured on the pulp of the first toe.

MATERIAL

The material consisting of 17 limbs of nine patients was selected on the criteria of a low systolic blood pressure on the great toe and a normal or only slightly decreased blood pressure at the level of the ankle. In normal subjects the systolic ankle blood pressure values are above the brachial arm blood pressure, the average difference between ankle blood pressure and arm blood pressure being + 20 mmHg ± 20 mmHg (mean ± 2.5 s.d.). In younger subjects (17–31 years) an ankle—toe difference of 43 mmHg or more is significant of arterial lesion with a confidence of 99 per cent and in elderly patients (43–57 years) a gradient of 64 mmHg is the criterion (Nielsen et al. 1972).

The clinical data are listed briefly in Table 1 together with the ankle and toe systolic pressures, the corresponding brachial systolic pressures and the ankle-toe differences as corrected for alterations in systolic brachial pressures. All pressures listed are the mean values of triplicate measurements. The blood pressure measured on the calf and on the thigh were normal in all limbs and these figures are not listed. There were eight male patients and one female. The ages ranged from 29–69 years (mean 54 years). According to the clinical criteria outlined by McPherson et al. (1963) three patients had thrombo-angiitis obliterans and six patients arterio-

Table 1.

Case no	Age sex	Leg	Clinical data	Pulsation in dorsal pedal artery	Pulsation in posterior tibial artery	Systolic ankle BP	Systolic arm BP	Systolic toe BP	Systolic arm BP	Ankle BP† –toe BP
1.	46	L	Slowly healing ulcer on the great toe	—	—	124	112	36	111	87
	♂		Intermittent claudication							
		R	Slowly healing ulcer on the great toe	—	—	127	112	36	111	90
			Intermittent claudication							
2.	62	L	No symptoms	—	+	173	162	95	150	66
	♂	R	Intermittent claudication	—	+	161	162	66	150	83
3.	68	L	No symptoms	+	+	200	171	98	176	107
	♂	R	Slowly healing ulcer on the great toe	+	+	177	171	34	176	138
4.	29	L	Slowly healing ulcer on the foot	+	—	141	131	54	135	91
	♀	R	(Proximal arterial occlusion – no symptoms)							
5.	69	L	No symptoms	+	—	233	219	155	216	75
	♂	R	Slowly healing ulcer on the foot	+	—	216	219	51	216	162
6.*	72	L	Chronic ulcer on the foot	—	—	146	164	44	164	102
	♂		Intermittent claudication							
		R	Intermittent claudication	—	—	154	164	52	164	102
7.§	46	L	Gangrene of the great toe. Rest pain	—	—	100	129	25	128	74
	♂	R	No symptoms	—	—	140	129	37	128	102
8.§	54	L	Chronic ulcer on the great toe. Rest pain	+	—	149	124	36	136	125
	♂	R	No symptoms	+	—	155	124	73	130	88
9.§	39	L	Gangrene of the fifth toe. Rest pain	—	—	142	130	30	130	112
	♂	R	Gangrene of the first toe. Rest pain	—	—	160	130	23	130	137

* Diabetes mellitus § Thromboangiitis obliterans † Corrected for changes in systolic arm BP

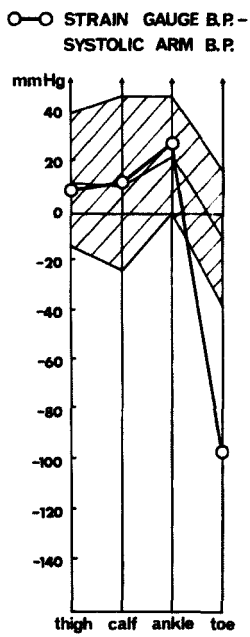

Figure 1. Systolic blood pressure measured at four different levels including the great toe (case no. 8, left leg). Normal values (mean ± 2.5 s.d.) are shown as the hatched area. Arm blood pressure is taken as a zero-reference-point.

sclerosis obliterans. Two of the patients with arteriosclerosis obliterans had diabetes mellitus.

Three limbs suffered from toe gangrene and severe rest pain. Seven limbs had chronic, non-healing or slowly healing ulcers localized in the toes or forefoot, in two cases associated with intermittent claudication. Two limbs suffered from intermittent claudication only, and five limbs were without symptoms, two of these had earlier had slowly healing toe ulcers. In the five limbs without symptoms the disease was detected during evaluation because of symptoms from the contralateral leg. In two limbs pulsations could be felt in both pedal arteries and in seven limbs pulsations could be felt in either the posterior or the anterior tibial artery. In eight limbs no pedal pulses could be felt. In all limbs normal pulsations could be felt in the femoral artery at the groin.

The presence of distal arterial occlusive processes was confirmed by angiography. In all limbs there was occlusion of one or two main arteries on the calf. All feet had decreased arterial supply, six feet were supplied only by collaterals, eleven feet were supplied only by the anterior or the posterior tibial artery, and this last main arterial pathway was furthermore occluded on the foot in three limbs. Three limbs had a slightly decreased ankle blood pressure. In one of these limbs the last patent artery on the calf was occluded just proximal to the ankle and in two limbs there were stenoses in the thigh arteries in addition to the distal occlusions.

Stenoses of the femoral arteries were also found in two limbs with a normal ankle blood pressure, but in none of the limbs were there arterial occlusions proximal to the division of the popliteral artery.

As an example of the distal arterial lesions the pressures from case no. 8, the left leg, are plotted on a diagram showing the normal pressure variations (mean

Figure 2. Angiography (case no. 8, left leg) showing occlusion of the posterior tibial artery (arrow). The peroneal artery is rudimentary. Only the anterior tibial artery is patent.

Figure 3. Angiography (case no. 8, left leg) showing the patent anterior tibial artery. Only the first segment of the dorsal pedal artery is intact. Occlusions are indicated by arrows. The posterior tibial artery is not visualized (see Figure 2).

± 2.5 s.d.) with the brachial systolic pressure taken as a zero-reference-point. The striking decrease in pressure from the ankle to the great toe is apparent. The arterial lesions in this leg are shown in Figure 2 and Figure 3.

The toe pressures correlated to the clinical condition. In three limbs with gangrene the toe pressures were 23–30 mmHg (mean 26 mmHg) and in seven limbs with chronic or slowly healing ulcers the pressures ranged from 34–54 mmHg (mean 42 mmHg). Two limbs with only symptoms of intermittent claudication had toe pressures of 52 and 66 mmHg and the five limbs with no symptoms, in spite of the distal arterial lesions, had toe pressures ranging from 37 to 155 mmHg.

DISCUSSION

Several authors (Strandness & Bell 1965, Strandness et al. 1966, Carter 1969, Yao et al. 1969, Bollinger et al. 1970, Thulesius 1971) have in recent years reported on the ankle blood pressure as a valuable quan-

titative measure of obliterative arterial disease. The present communication was stimulated by the occasional finding of a limb with a normal ankle blood pressure and a low toe blood pressure, pointing to an arterial lesion localized very peripherally. These lesions, which in all limbs were verified by angiography, were often difficult to recognize by the clinical examination, especially when pedal pulses could be felt. Ischemia should always be suspected in case of a chronic pedal ulcer and the diagnosis may certainly be verified by angiography. But a clear-cut quantitative diagnosis is easily obtained by measuring the blood pressure on the ankle and toe. Furthermore the healing of skin lesions in areas of arterial insufficiency is strongly correlated to the local blood pressure (Carter 1973, Holstein 1973) and thus the pressure measurement is the key to the proper therapy.

An abnormal pressure drop between ankle and toe suggests arterial lesion in the arteries of the foot or digits. This was confirmed by angiography, but in all limbs there was also obliteration of one or two main arteries in the calf. A normal blood pressure measured on the ankle by the strain gauge technique may thus be maintained by one patent artery, either the posterior or the anterior tibial artery or the peroneal artery. It should be emphasized that the present method of measuring the distal blood pressure cannot detect occlusion localized in arterial side branches as long as a main arterial pathway is intact. Similar observations with regard to peripheral occlusive processes and a large ankle-toe difference have been reported by Carter & Lezack (1971).

Distal arterial occlusions are not necessarily associated with symptoms. Five legs in this series were without symptoms and did not even suffer from intermittent claudication. A decreased activity because of symptoms from the other leg in these patients should be mentioned as a possible explanation for the lack of pain during exercise. However, these patients often become completely free of symptoms and fully active if skin lesions heal, and a decreased activity is therefore not the reason for the lack of pain during walking. It is worth pointing out that patients with distal arterial lesions may present a chronic or slowly healing skin lesion as the only sign of disease. In spite of obliteration of one or two calf arteries, one patent artery is apparently sufficient to supply the calf muscles during walking and the blood supply to the foot may be sufficiently maintained by collaterals.

A wide range of pressures were found in the legs without symptoms. In the case of mild disease the blood pressure on the toe is only slightly decreased and when the systemic blood pressure is high, the toe blood

pressure may also be quite high. Low pressure on the toe is caused by severe occlusive process, but may also exist in mild disease if the systemic blood pressure is low. As is evident from this series it is the limbs with a low toe blood pressure that may present impaired wound healing.

The distal blood pressure can be measured by various methods and some of these require very little equipment. By the flush technique (Carter 1969) the systolic blood pressure is detected by watching carefully the skin during stepwise deflation of the cuff. A pink colour and a swelling of veins indicates that blood is escaping under the cuff. We prefer the strain gauge technique, because the pressure is recorded objectively by a curve. The technique is suitable for bedside use, being quick and simple. The sensitivity of the detector is quite high and even minimal volume expansion is registered. A wide range of pressures from about 5 mmHg to over 200 mmHg can be picked up and the values obtained are well correlated to the clinical condition (Gundersen 1972) and angiographic findings (Carter & Lezack 1971, Bell et al. 1973). The presence of ulcers, even patchy gangrene, on the great toe does not necessarily hinder the pressure measurement on this site. In addition, the pressure values are expressed in *millimeters of mercury*, which is easy to communicate to all members of a medical staff.

Occasionally a stiff arterial wall may cause too high a pressure value, but this type of error is, in general, recognized when measuring the blood pressure at more than one level, and in cases where a segment of the extremity has shown an unreasonably high pressure value, we have found that the artery under the cuff appeared as a calcified tube on a plain X-ray. On the toe level, the transmission of pressure from the cuff to the small digital arteries is probably reliable. Solitary high pressure values at this distal level have not been observed.

It should be mentioned that pressure measurements should be performed at comfortable room temperature, so that the skin temperature on the toes is between 22° and 33° (Celcius), otherwise the recorded values may be too low (Gundersen 1972).

By measuring the blood pressure on the ankle and toe the most threatened part of the extremity is evaluated, and thus these measurements are valuable for all patients with obliterative arterial disease of the limbs. In this paper we have commented on the *distal* arterial occlusion because the toe blood pressure gives a quantitative diagnosis, which otherwise is difficult to obtain.

SUMMARY

Measurement of the ankle blood pressure fails to reflect occlusive arterial disease localized in the arteries in the lower leg and foot and a clinical assessment of the disease may be difficult. A quantitative diagnosis can easily be obtained by measurement of the toe blood pressure. Measurements in 17 limbs with such distal obliterative arterial processes are reported.

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