Acta Thermographica Supplement

- Deep Vein Thrombosis -

I . Introduction

Pulmonary embolism (PE) is the most common acute pulmonary disease in hospital practice.[1, 2] Current estimates of the annual mortality in the United States vary from 20,000 to 200,000 cases.[3, 4] Furthermore, some 300,000 cases of deep venous thrombosis (DVT) require hospitalization each year.[6, 7] Such figures indicate the extent of the problem and are an expression of the incidence in Western Society. To the individual clinician, who may perhaps see only two or three ***clinical*** eniboli each year, such estimates may appear exaggerated. There is good evidence to the contrary. Detailed postmortem studies show an increase of twenty-fold of PE as the certified cause of death in patients undergoing postmortem when contrasted with those in whom this examination is not performed.* It has been established that fatal embolism may be the only cause of death in eight percent of cases and contributory in thirteen percent. This is explained by the frequency with which deep venous thrombosis(DVT) complicates other illnesses such as surgery,[1, 2] myocardial infarction,[13, 14] stroke,[15,16] and confinement.[17] Oestrogen therapy, particularly oral contraception, also carries a small but significant risk [18, 19] and in some cases, e.g. 'idiopathic' recurrent DVT, the aetiology is not clear.

Pulmonary embolism often occurs unexpectedly because DVT is characterized by the absence of clinical signs even when the thrombus is extensive and life-threatening.[20] Moreover, the presence of clinical signs is not a certain indication of DVT.[21, 22, 23, 24] Thus dependence on clinical evidence only means that there are, on the one hand, a large number of patients at immediate risk to whom therapy is not available and, on the other, a group with misleading signs who may be exposed to the dangers of anticoagulation unnecessarily.

II . Risk Factors in Venous Thromboembolism

It has long been recognized that any patient at enforced bedrest may develop a thrombus in the leg veins.[25, 26] However, the following categories are at special high risk:

Surgery

Major general surgery,[21, 22, 23] especially for malignancy [27]

Orthopaedic surgery [6, 28, 29]

Trauma, including severe burns [30, 31]

Medical

Cardiac [13, 14]

Neurological [15 16]

Obstetrics and Gynaecology [17, 32]

Previous History of Thromboembolism [33, 34]

Oestrogen Therapy, in particular, Oral Contraception [18, 19]

Thirty percent of patients undergoing major general surgical procedures develop a calf vein thrombosis.[35, 36] While the majority of these thrombi undergo spontaneous lysis or remain in the calf, twenty-five percent propagate to the axial thigh veins and are a potential source of major emboli. When surgery is for malignant disease there is a significant increase in incidence. Orthopaedic patients are at particularly high risk.[6] Thigh vein thrombi have been recorded in more than fifty percent of patients undergoing elective hip surgery.[37, 38] The incidence of embolism may be greater than one in ten [20, 29] and the fatality rate from this cause alone three to four percent. Extensive trauma, particularly to the spine, pelvis and long bones of the leg, and severe burns are associated with a similar or even higher incidence.

Perhaps because of the long periods of immobility associated with non-surgical disease,

the number of cases on the medical wards in also unacceptably high. This is particularly so in cardiology and neurology where eight percent of deaths may be due to pulmonary embolism alone.

The recent success ofprophylactic measures may lead to the erroneous impression that early diagnosis of thromboembolism is less important than previously. On the contrary, from this short synopsis of risk factors it will be evident that the present measures available are only applicable to a small number of the total population in whom the disease is a potential hazard. Many patients present in hospital from domiciliary practice with a possible diagnosis of DVT while in others, for various reasons, prophylaxis may be contraindicated or seem unnecessarily wasteful.

Ill - Signs and Symptoms of Deep Venous Thrombosis '

A number of investigations have shown that the classical, clinical signs of deep venous thrombosis, calf pain and tenderness, Homans' sign, oedema and induration, and an increase in limb temperature are unreliable[39] (Fig. 1). Pain is subjective and a common complaint in many patients who have been confined to bed for more than a few days. Equally, the sign of calf tenderness is a common finding even in healthy, active individuals. Again, the presence or absence of Homans' sign (pain in the calf on passive forced dorsiflexion of the foot) is frequently misleading. It is commonly absent when DVT is exten-

CLINICAL'FINDINGS

	NO. OF CASES	DIFFERENCE IN LEG TEMPERATURE AFTER EXPOSURE	DIFFERENCE IN MAXIMAL GIRTH OF CALF>1 CM.	CALF TENDERNESS	HOMANS SIGN
D.V.T.	50	24	22	18	10
NO D.V.T.	50	14	8	16	6

Fig. 1. Clinical findings in the legs made by unbiased observation of one hundred (100) consecutive cases after elective hip surgery in which the presence or absence of DVT was demonstrated by phlebography.

COMPARISON OF THERMOGRAPHIC AND CLINICAL OBSERVATION OF DIFFERENCES IN LEG TEMPERATURE

CLINICAL OBSERVATION	NO. OF LEGS
No temperature difference detected	28
Temperature difference detected:	
Before thermographic diagnosis	4
The same day as thermographic diagnosis	5
After thermographic diagnosis	12

Fig. 2. In 49 phlebographically-proved cases of DVT in which the temperature difference was shown by thermography, the detection of difference in leg temperature by palpation was found to be completely unreliable.

sive and may be elicited in the absence of thrombosis. The most reliable sign of DVT is an inequality of limb temperature most easily detected as delayed cooling of the involved limb after a period of exposure. However, thrombosis is often bilateral, and even when unilateral, the sensitivity of the palpating hand is such that small temperature differences, though significant, may not be detected (Figs. 2 and 3).

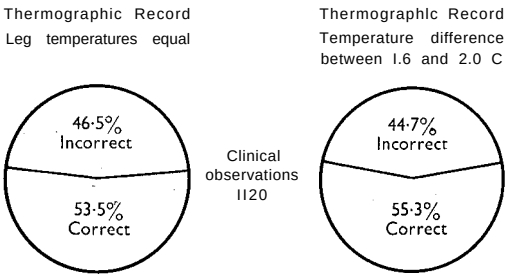


Fig. 3. In 1,120 unbiased, clinical observations for differences in leg temperature, it was found that palpation does not consistently detect temperature differences of 2°C or less.

Moreover, with the exception of acute massive embolism, the signs and symptoms of pulmonary embolism are also often misleading[40,41] or obscured by the primary illness.[42] Dyspnoea, tachycardia and chest pain, the common findings, are associated with a multiplicity of other diseases.

From the above considerations it is easy to see why venous thromboembolism is often missed or not considered or, conversely, falsely diagnosed. In no other common disease is there a greater need for an accurate method of non-invasive diagnostic scanning in patients with symptoms or who are at risk.

IV - Evaluation of Available Techniques for Diagnosis of DVT

The unreliability of clinical signs and the large number of patients at risk indicates the necessity for an accurate, diagnostic technique which is readily available, may be used for daily scanning, is not time consuming, is simple to interpret and universally acceptable. None of the available techniques fulfill all these criteria.

Phlebography is the most accurate means of detecting the presence of a deep venous thrombus and is the base-line against which the sensitivity and specificity of other diagnostic methods is measured. However, the technique is time consuming and requires skilled medical and radiological personnel in contrast to other techniques which require only a single, specially trained technician. Logistically it is not suitable for screening and is likely to be used only when there are strong, clinical indications or when other techniques yield positive results.

^{125}1-Labelled Fibrinogen Uptake Test is an accurate means of detecting calf vein thrombi when patients are studied prospectively but a positive result is dependent on the continued uptake of labelled fibrinogen by the thrombus. It is inaccurate in thigh vein thrombi[43,44,45] when the risk of significant embolism is high and is contraindicated during pregnancy and lactation.[46] No large scale studies exist for the evaluation of this test in symptomatic patients. The papers presently available suggest an accuracy of eighty percent in calf vein thrombi.[47,48] Used as the sole means of detection in symptomatic patients, its value must remain doubtful until evidence to the contrary is available. Is should be noted that there is a delay of twenty-four hours before confirmation of the diagnosis when this test is used.

Transcutaneous ultrasound is valueless in screening high risk patients[49,50] and lacks sensitivity and specificity in symptomatic patients.[51]

Impedence and straln gauge plethys-

mography may suffer from the same limitations.[52, 53, 60]

Blood screening techniques are either highly specialized and expensive to perform or relatively insensitive. They all suffer from the disadvantage of indicating thrombosis at any body site and are not specific for DVT.

The only non-invasive technique which fulfills the above criteria and has been shown to be of value in scanning high risk asymptomatic patients[39] and symptomatic patients[56, 57, 58, 59] is **Thermography** which is the subject of this monograph (See Chart 1).

V. Methodology, Materials, and Procedures

In order to obtain high quality thermograms, which will provide an accurate image of the leg temperature and thus facilitate interpretation, care must be taken to avoid conditions which are likely to cause error.

ROOM CONDITIONS

Ensure that the examination room is free of all draughts and air currents or sources of direct heat such as sunlight or a nearby radiator. Ideally, the air temperature should not exceed 20°C (68°F). However, this is not absolute. More important is a stable temperature, in order to obtain reproducible results.

PREPARATION OF PATIENT

Patients may be examined during hospitalization or on referral from outpatient departments. During routine observation of hospitalized patients, e.g. following surgery, the patient should rest in bed for some time (fifteen to twenty minutes) prior to the thermographic examination provided that they have not been sitting with legs crossed or undertaking some activity which creates unrepresentative thermal patterns, e.g. exercise or stress on the limbs (Fig. 4).

Remove all bandages from the legs and feet at least two hours before examination. Physiotherapy to the lower extremities ideally should be delayed until after the thermographic examination or have taken place at least two hours before.

It is necessary to obtain thermal equilibrium between the legs and the surrounding ambient temperature before commencing the examination. Thus, to be certain that this is achieved, the patient lies supine and is exposed to the umbilicus for fifteen minutes. The legs are externally rotated with the ankles four inches to six inches apart. The leading or lateral edge of the tibia faces upward. The ankles are elevated by a rubber pad 10° or more above the horizontal ensuring that the calves are fully suspended and venous pooling is avoided. Legs examined in the horizontal position may produce a rise in limb temperature which makes accurate interpretation of the thermogram more difficult (Figs. 5 and 6). Tightly fitting pants or briefs in particular may also obstruct the circulation and produce heat conservation. For patient modesty and comfort the pubic area may be covered with a paper towel or something similar. Powder or lotions interfere with radiation and should be ***gently*** removed from the area to be examined some time before thermography is performed.

Instruct the patient to keep hands off the legs to avoid thermal artifacts. The patient should keep this position for the entire cooling period.

The same preparation should be utilized for the examination of outpatients referred because of their symptomatology.

THE THERMOGRAPHIC SYSTEM

The thermographic system consists of a scanning camera with a display unit. Infrared radiation from the object which is being examined falls on an optical system in the camera

Chart. 1. **COMPARISON OF THE ACCURACY, SPECIFICITY, AND SENSITIVITY OF SOME OF THE TECHNIQUES AVAILABLE FOR THE DIAGNOSIS OF DEEP VENOUS THROMBOSIS OF THE LEGS +**

METHOD	ACCURACY		SPECIFICITY	SENSITIVITY	COMMENT
	ASYMPTOMATIC PATIENTS	SYMPTOMATIC PATIENTS			
Clinical	v. low	v. low	v. low	v. low	The most'valuable clinical sign is a generalized increase in limb temperature; not commonly sought; detectable in < 50 percent of cases. Other clinical signs often misleading; pulmonary embolism common when legs apparently normal.
Phlebography	high	high	high	high	Invasive: basic technique against which accuracy of other methods compared, time consuming, requires highly trained staff. Only means by which thrombus <<visualized >>. Not suitable as monitoring technique.+
^{125}I-labelled Fibrinogen Uptake test	high for CVT	moderate	high for CVT	high for CVT	Invasive, accuracy limited to calf and lower 2/3 of thigh.@
Transcutaneous Ultrasound	low	moderate	low	low	Non-invasive: valueless in calf vein thrombosis. Positive findings depend on venous occlusion.
Impedence Plethysmography	moderate in TVT low in CVT	moderate in TVT low in CVT	low in CVT moderate in TVT	moderate	Non-invasive: positive results depend on venous occlusion, thigh vein thrombi more likely to be detected than CVT.
Strain Gauge Plethysmography	low for CVT and non-occlusive TVT	low for CVT and non-occlusive TVT	low	low	Non-invasive: principal value appears to be in occlusive thigh or ileo-femoral thrombi.
Blood Tests (1) Global	low	low	low	low	Do not indicate site of thrombosis which may be anywhere in the body.
(2) Specific (a) HMWFRC (b) FGE	high high (PE only)	unknown high in major episodes	high high	high high	
Thermography	high	high	high	high	Non-invasive.

\+ Compilation of published papers
✦ Contraindicated during pregnancy
ø Contraindicated during pregnancy and lactation
TVT Thigh vein thrombus
CVT Calf vein thrombus
HMWFRC High molecular weight fibrin related complexes
FgE A terminal product of fibrin digestion
High: Greater than 85 percent
Moderate: >70 percent <85 percent
Low: 70 percent or less

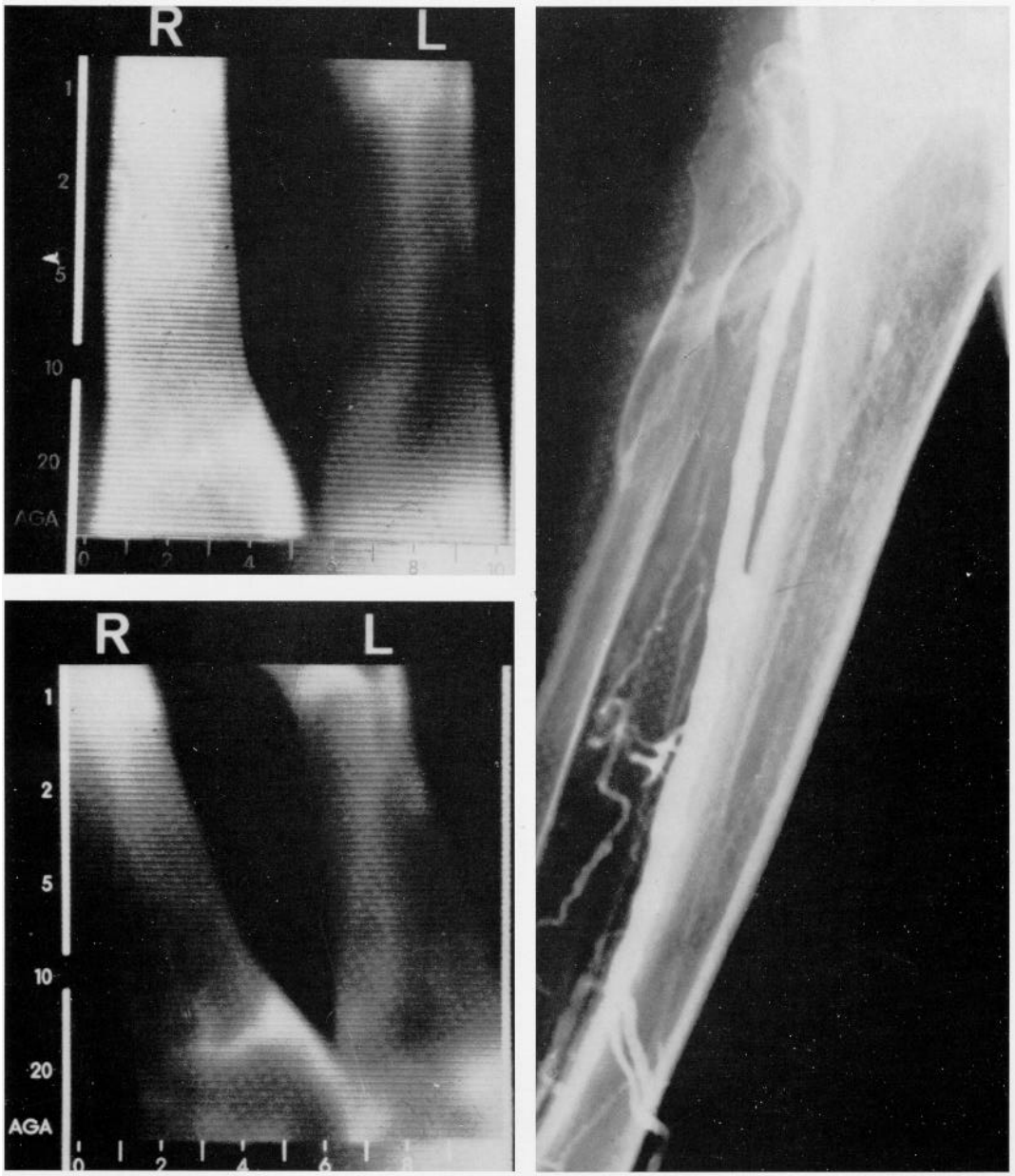


Fig. 4. Upper left thermogram shows generalized increase in temperature of the right leg in an elderly female after sitting with legs crossed. These appearances may persist for many hours. Lower left thermogram shows the same patient after lying overnight with the legs horizontal. Note normal phlebography of right leg.

and is focused on a single element indium antimonide detector. This detector is cooled with liquid nitrogen to attain high sensitivity in the infrared spectral band. A video signal is produced, amplified, and conveyed to the display unit where it controls the electron beam of a television monitor tube. The beam scans the screen of the monitor synchronously with

Fig. 5. Position of patient and elements of the thermographic system when legs are being examined for deep venous thrombosis. Patient supine.

the camera scanning the object (16 fields/set). A high degree of spatial and thermal resolution is attained.

INSTRUMENT OPERATION AND PROCEDURE

Prepare the equipment in accordance with the manufacturer's instructions making sure that the equipment is filled with liquid nitrogen.

Position the camera at the foot of the bed and the front surface overhead mirror over the legs so that the heat radiated from the legs is directed into the camera (Fig. 5) and in such a way that the area of investigation takes up a maximum of space in the thermographic image. As with x-ray examination some device should be used to indicate the right or left side of the body.

Thermograms of the calves should include the area from at least the lower half of the patella to just above the malleoli. The latter may not always be possible in tall patients with long calves. However, views which omit the distal calf are likely to yield adequate information.

Thermograms of thighs should cover an area from about four inches above the pubis down to just above the patella. An image covering a larger area may be less easy to interpret.

When the anterior views of the calf and thigh have been obtained, the patient should

be turned to the prone position to examine the posterior aspect of the calf. The prone views of the calf may be taken without an additional cooling period and must include the popliteal fossa to just above the' ankle joint. A prone view of the thigh would require an additional period of cooling because the posterior aspect of the thigh is in contact with the bed during the period when supine views are obtained. However, to date, examination of the posterior aspect of the thigh has not yielded any useful information.

If repositioning of the limbs is necessary, instruct the patient accordingly or otherwise handle only the great toe or sole of the foot as lightly as possible. ***Do*** not touch the surface to be thermographed.

If using the AGA instrument, settings should be:

- *Preset/adj. manual* knob to No. 1

– ***Temperature sensitivity*** knob to No. 1 (1° C/DIV)

- ***Polarity*** knob to one usually employed ***(Normal/white = hot*** or ***Inverted/black= hot)***

Focus the camera lens accurately to produce a sharp image with well defined features showing a maximum number of grey tones. This is usually achieved by focusing accurately on the tibia or mid thigh and when the transitional area on the grey scale is to the right of center. Use a pointer or similar object placed on the mid part of the thigh or calf as a focusing aid and remove it before recording

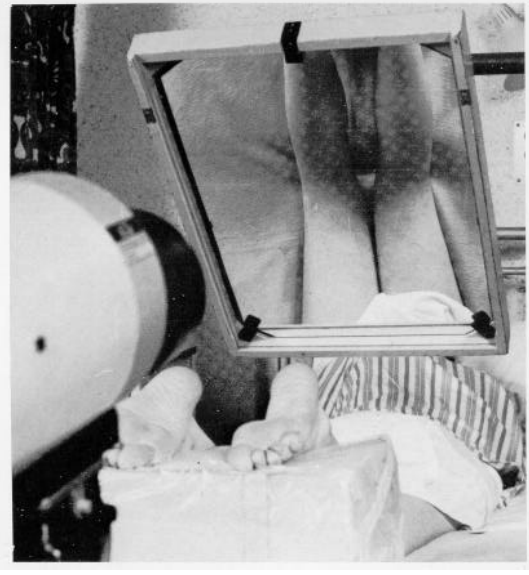


Fig. 6. Position of patient and etements of the thermographic system when legs are being examined for deep venous thrombosis. Patient prone.

thermograms. A too black, too white image (Figs. 7 and 8) may cause difficulty in interpretation in some cases. Additionally, a blurred picture (Fig. 9) may create the false impression of a diffuse temperature increase when there is actually normality.

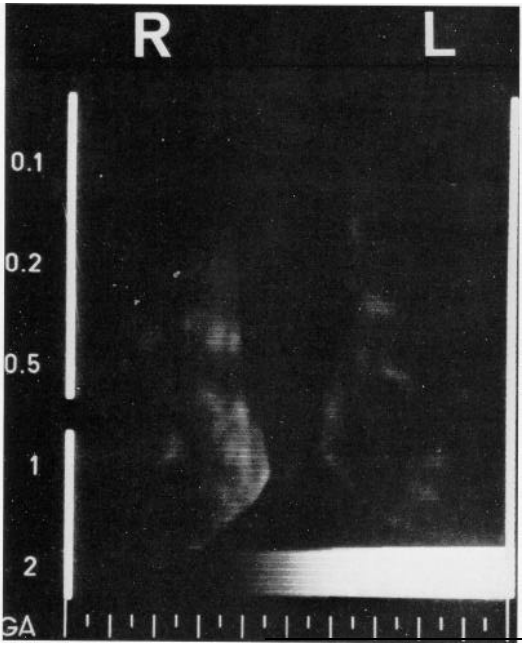


Fig. 7. Example of <<too black>> thermogram.

The correct brightness is selected by adjusting the ***middle temperature level*** control knob to the setting where the coolest area of the image is just slightly brighter than the background black. In the majority of cases this single adjustment is sufficient. However, some examiners may find it helpful to further darken the image in order to define clearly the characteristics of the image, in particular, the margin or edge of areas at increased temperature. (Discrete lesions have a well-defined edge while DVT has not. See criteria for diagnosis in Chapter VI).

Instruct the patient to keep still during the photographic recording of the image. In the case of Polaroid film, compare the result with the image on the display to make sure that it accurately represents the appearance.

While the above procedure demonstrates the presence or absence of an acute deep venous thrombosis, a prone view of the calf may provide additional evidence when a localized condition exists or diagnosis is less than certain.

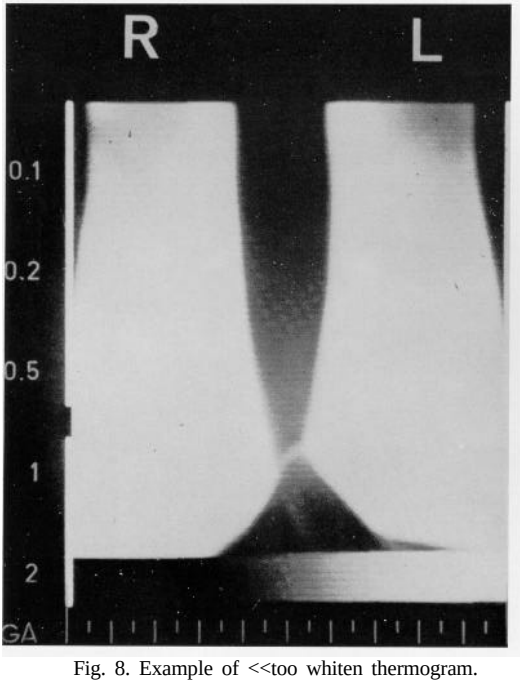


Fig. 8. Example of <<too whiten thermogram.

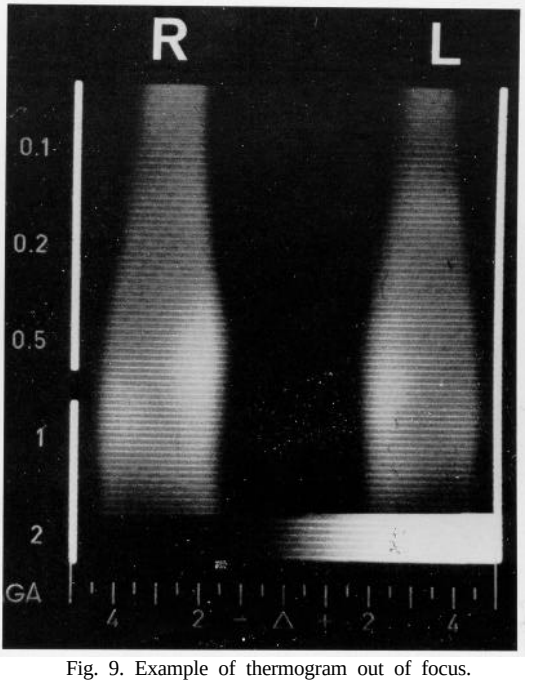


Fig. 9. Example of thermogram out of focus.

Chart **2. REQUEST FORM FOR A THERMOGRAPHIC EXAMINATION**

SURNAME	OTHER NAMES	UNIT NO.
CONSULTANT	WARD/DEPT	AGE

1. PRIMARY DIAGNOSIS:
2. PRESENT COMPLAINT AND SPECIFIC CLINICAL FINDINGS, particularly with reference to the legs and chest:
3. PREVIOUS HISTORY:
   a) SURGERY, with dates
   b) PERIODS OF BED REST:
   c) NO. OF PREGNANCIES:
   d) DRUGS: (including oral contraception)

DATE SIGNATURE PREVIOUS THG YES/NO

THERMOGRAPHIC REPORT

CONCLUSION

DATE SIGNATURE

Asymptomatic patients at high risk of deep venous thrombosis, for example after surgery, myocardial infarction or stroke, should ideally be studied serially, the examination being performed daily when possible. If this is not possible, then serial studies are best performed during the time when the incidence of thrombosis is known to be highest. For example, since the majority of venous thrombi are thought to form either during surgery or shortly afterwards, examination on the third or fourth day would be appropriate when significant propagating thrombi are most likely to be detected.

Study of symptomatic patients should be carried out as soon as possible after the patient has symptoms either in the legs and/or chest and always prior to initiating treatment. A positive thermogram, especially when thigh vein involvement is suspected, should be an indication for phlebography while a negative thermogram will indicate that no further action is necessary. Whenever possible the legs of all symptomatic patients with a normal resting thermogram should be exercised by running on the spot or on a tread mill for 2-3 minutes. (See Chapter VI on thermography and the postphlebitic syndrome). As with all special investigations, patients referred for thermographic examination of the legs because of suspected DVT should be accompanied by a request form which includes the patient's history and clinical observations (Chart 2). Special reference should be made to the observation of a palpable rise in limb temperature or a temperature difference between limbs.

VI . Criteria for the Diagnosis of DVT Utilizing Thermographic Interpretation

Before considering the criteria for the diagnosis of thrombosis in the deep veins of the leg, it is important to realize that the increase in limb temperature, which is associated with this disease and which is shown by thermography, is a phenomenon which may occasionally be observed clinically (vide infra) and which basic studies have shown might be expected to occur. For example, activation of coagulation is associated with the activation of other biological systems through the activity of activated coagulation Factor XII (Hageman Factor). The actions of this enzyme include the activation of the librinolytic, kininforming, and complement systems. Furthermore, one action of thrombin is the platelet release reaction. Thus the formation of a venous thrombus is associated with the local release of a number of vasoactive amines (Fig. 10) so that there is an increase in the resting blood flow(60) and thus the temperature of the limb. However, deep venous thrombosis is only one of the conditions which produce an alteration in the temperature of the resting, supine limb. Thus interpretation of leg thermograms is essentially concerned with (a) recognition of the normal thermographic appearances of the resting, supine limbs after a period of cooling; (b) recognition of the thermographic appearance associated with recent deep venous thrombosis; and (c) recognition of the thermographic appearances associated with those other conditions which produce an elevation or alteration in limb temperature.

THERMOGRAPHIC APPEARANCES OF NORMAL LEGS

In the absence of deep venous thrombosis and other conditions which produce alteration in leg temperature (see below), the thighs and calves show an overall cool appearance with tones which are on the cooler side of the grey-scale (Figs. 11, 12, 13). In the calf, the subcutaneous border of the tibia and the patella are the cooler (darker) areas in contrast to the surrounding muscles which are at slightly higher temperature. These areas are of particular interest in the diagnosis of deep venous thrombosis. Small localized « hot spots », especially if situated on the outer aspect of the thigh, can be ignored or subtracted from the overall thermographic appearances. Occasionally, small «hot spots » are widely distributed on the thermogram producing the so called « mottled » or « leopard spot » thermogram (Fig. 14). This phenomenon is not well understood. It occurs in other areas of interest e.g. breasts (Fig. 15) and is usually characteristic of that particular patient. Once recognized, the appearances can be subtracted from the overall thermographic appearance which facilitates diagnosis.

THERMOGRAPHIC APPEARANCES IN CALF VEIN THROMBOSIS

Recent calf vein thrombosis produces a diffuse increase in temperature which may involve the whole or greater part of the calf.

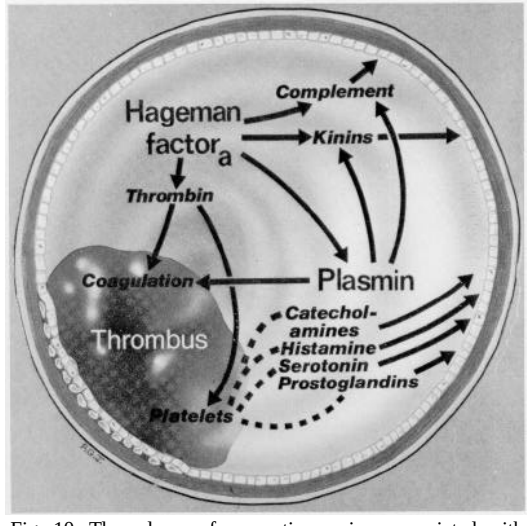


Fig. 10. The release of vasoactive amines associated with thrombus formation.
(-Action --Release)

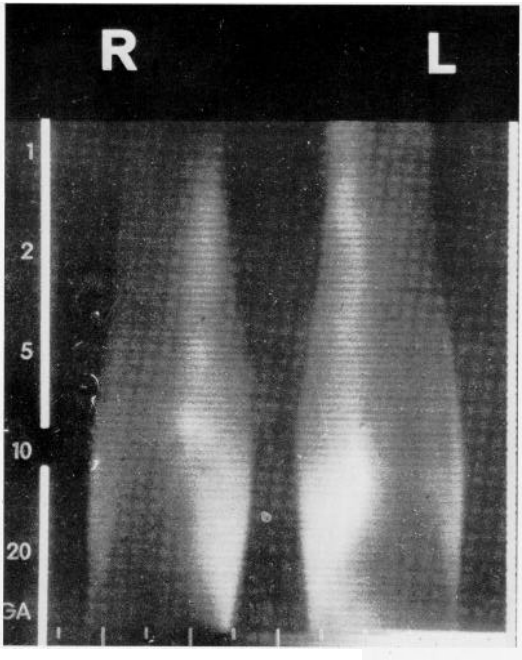


Fig. 11. The thermographic appearance of normal calf in the supine, legs elevated posture. Note the overall cool appearance, preponderance of dark grey-tones, and the sharp outline produced by the tibia and patella which are coolest areas. (In this polarity, dark areas are cool and light areas are hot).

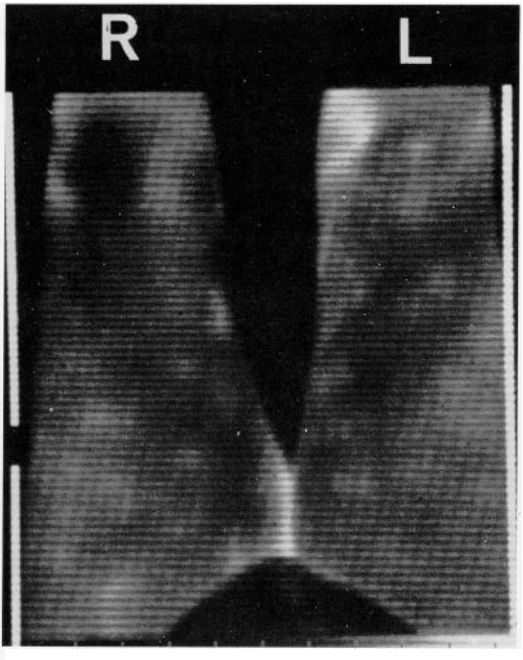


Fig. 12. The thermographrc appearance of normal thighs in the supine, legs elevated posture. Note the overall cool appearance and preponderance of dark grey-tones. (In this polarity, dark areas are cool and light areas are hot).

The temperature increase is evident on both supine and prone views (Fig. 16), when the latter view can be obtained, and is characterized by two features (a) disappearance of the whole or greater part of the normally clearly defined tibia1 area and (b) by an ill-defined edge (margin) to the area of increased temperature. Variations of these appearances are:

1. The ((white-out)> appearance (Fig. 17) - in this the temperature increase is such that the whole of the calf from ankle to patella is at marked raised temperature. There is no edge to the area of increased temperature which is limited only by the dimensions of the limb which may appear larger than the contralateral side. These appearances are often seen in the absence of leg oedema or other clinical signs. The « white-out » appearance is often associated with the loss of the cool area of the patella and usually indicates massive calf vein thrombosis which is propagating to the thigh.

2. A small, ill-defined area of temperature

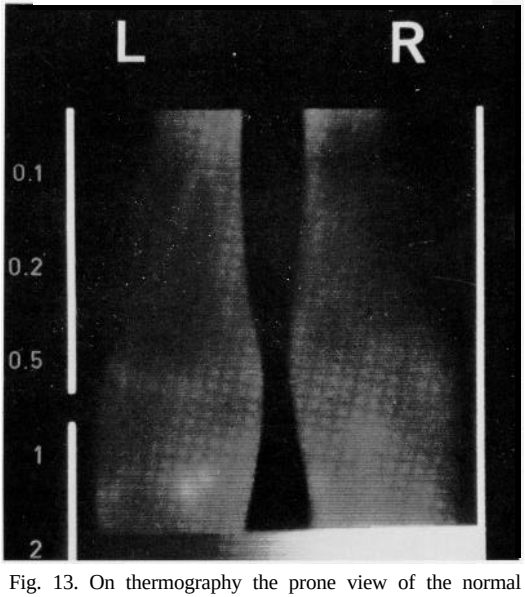


Fig. 13. On thermography the prone view of the normal calf shows an overall cool appearance with the grey-tones on the cooler side of the grey-scale. The popliteal fossa is the warmest area. (In this polarity, dark areas are cool, light areas are hot).

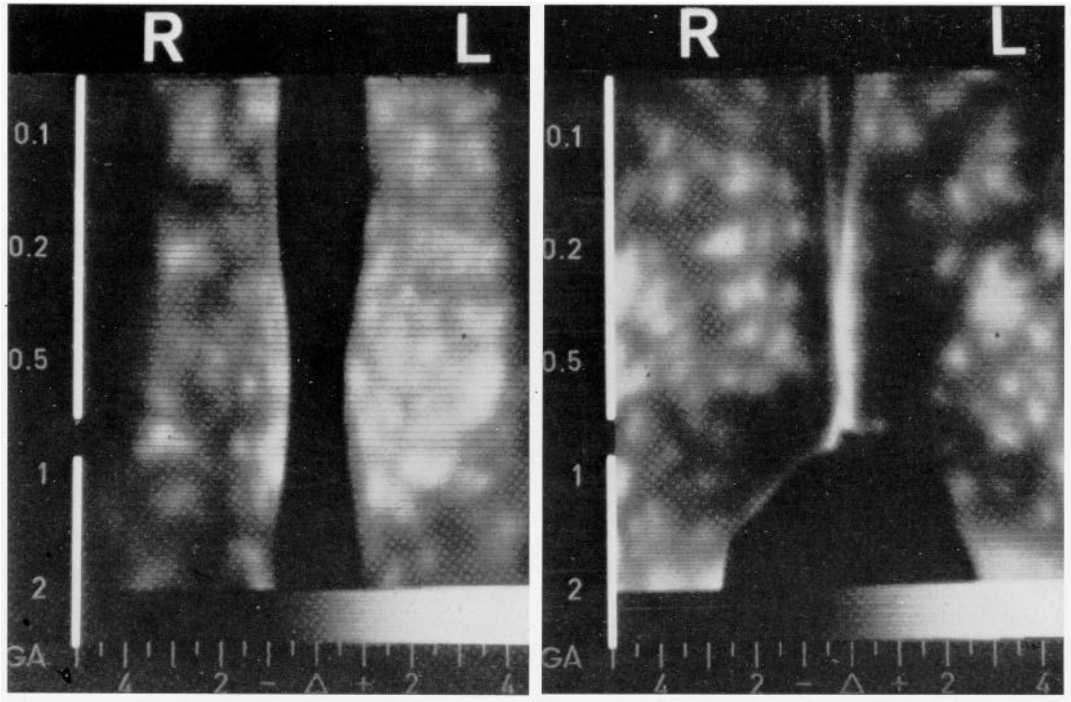


Fig. 14. An extreme example of the mottled or leopard spot thermogram of the legs

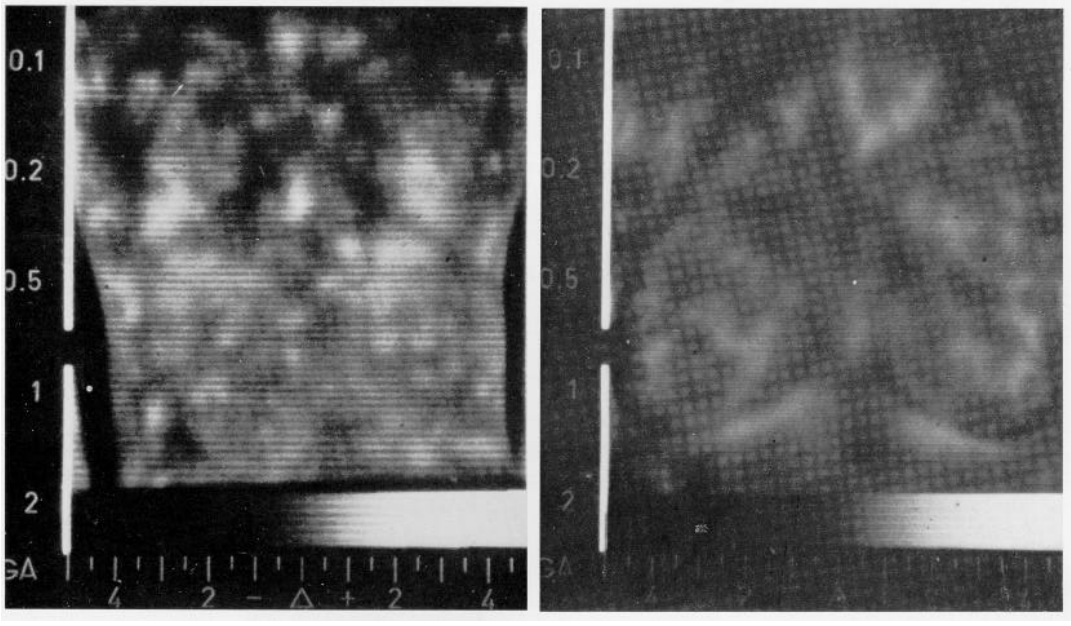


Fig. 15. Mottled or «leopard spot» thermogram of abdomen and breasts. (Same patient as Fig. 14)

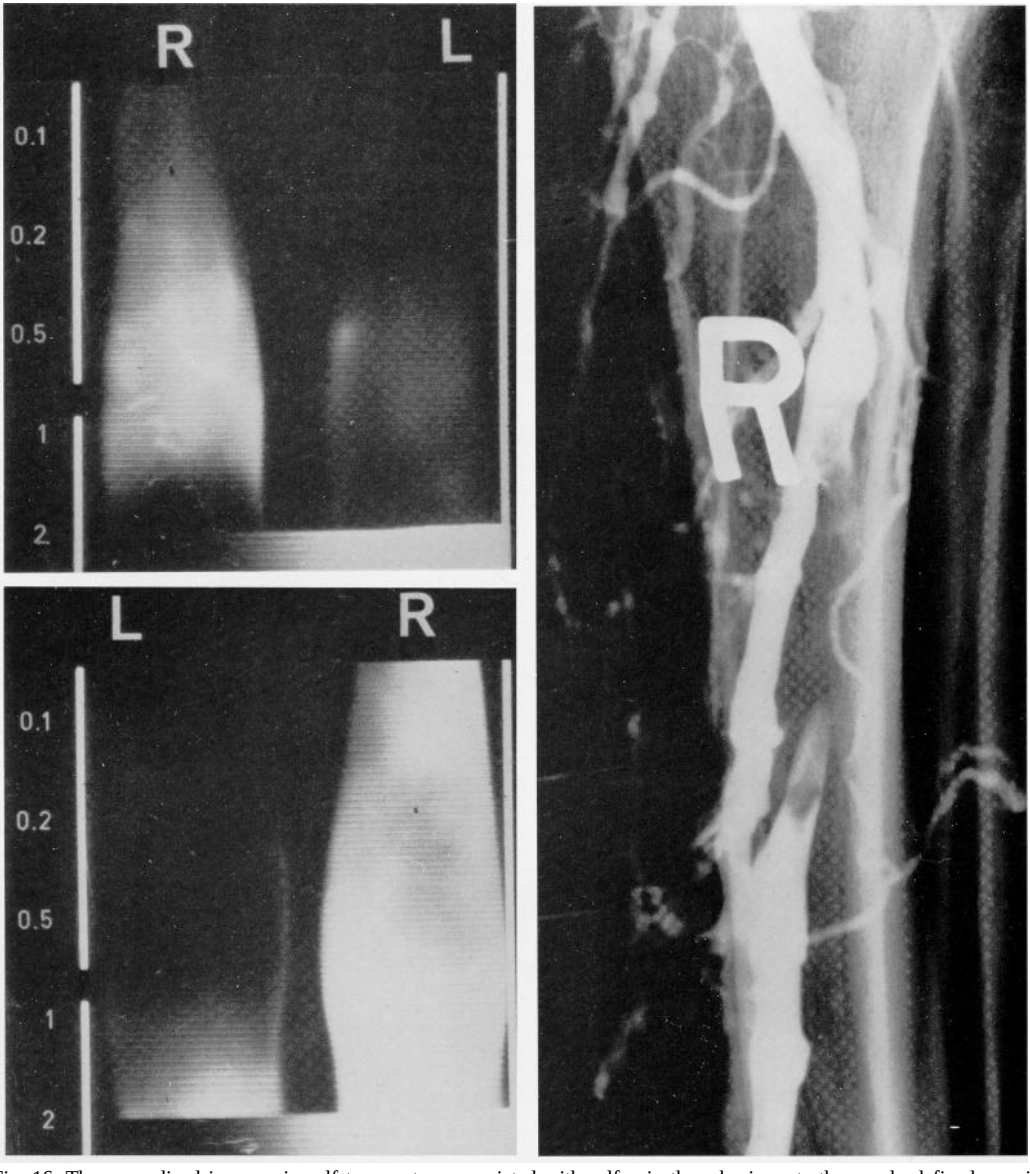


Fig. 16. The generalized increase in calf temperature associated with calf vein thrombosis: note the poorly defined margin to the area at increased temperature. Top left: patient supine; Bottom left: patient prone; Right: the phlebography shows the typical appearances of a recent calf vein thrombus.

increase situated usually medially in the calf. These appearances may be associated with small posterior tibia1 or soleal vein thrombi (Fig. 18).

3. A medially placed triangular area of increased temperature with its base at the inferior aspect of the popliteal fossa has been observed to be associated with the uncommon condition of thrombosis isolated to the gastrocnemeal veins (Fig. 19).

Though usually comparison with the contralateral calf will facilitate interpretation, it is important to realize that approximately thirty percent of calf vein thrombi are bila-

teral so that abnormal appearances may be present in both legs (Fig. 20).

THERMOGRAPHIC APPEARANCES IN THIGH VEIN THROMBOSIS

Fresh thrombosis of the thigh veins characteristically produces a diffuse increase in the temperature of the medial thigh. The edge or margin of this area is again poorly defined merging gently into the cooler area of the lateral thigh (Fig. 21). The size of the area at increased temperature varies from a segment running in the long axis of the limb to a large' area involving the greater part of the thigh (Figs. 22 and 23). The latter appearances are usually associated with more proximal thrombi situated in the common femoral and iliac veins (ileo-femoral thrombi). Occlusive thrombi in this area may be associated with a series of linear « hot spots » radiating from the center and medial aspect of the inguinal ligament which are probably due to dilated superficial collateral vessels (Fig. 24). These should not be confused with the dilated veins radiating from the site of the wound which occasionally occurs after hip surgery. Such vessels are always confined to the lateral aspect of the thigh (Fig. 25).

OTHER CONDITIONS WHICH PRODUCE AN ELEVATION OR ALTERATION IN LMB TEMPERATURE

In contrast to deep venous thrombosis, the other conditions which produce an elevation or alteration in limb temperature are usually easily recognized on clinical examination and do not require thermographic examination in order to determine the diagnosis. Moreover, the thermographic appearances of these conditions are usually characteristic and easily distinguishable from deep venous thrombosis.

The common conditions seen are the arthritidies (Figs. 26 and 27), varicose veins (Figs. 28 and 29), superficial thrombophlebitis (Fig. 30), inflammatory conditions of the skin (Fig. 31), traumatic haematoma (Fig. 32), diseases of bone e.g., tumor (Fig. 33), Paget's disease (Fig. 34), and rupture of a Bakers cyst (Fig. 35). These conditions produce « hot spots » which vary in size and distribution and have a clearly defined margin. A « cold » limb is produced by paralysis (Fig. 36) and peripheral vascular disease (Fig. 37).

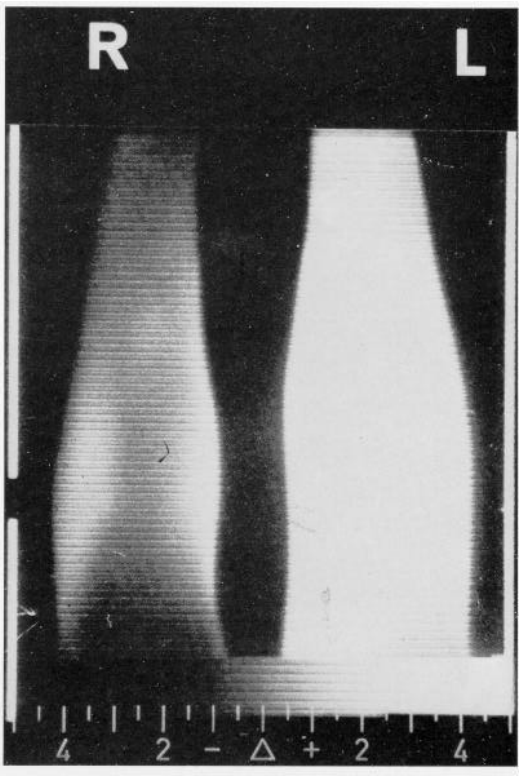


Fig. 17. An example of a «white-out» thermogram. This is often seen in clinically normal legs and usually indicates extensive DVT propagating to the thigh.

THE ARTHRITIDIES

Synovitis and arthritis produce thermographic changes which are, as expected, limited to the area of the knee joint (Figs. 26 and 27). They vary according to the activity of the disease. For example, osteoarthritic joints may be cool or show only a few dilated veins in the joint area, while an acutely active arthritic knee may be «white hot». Since rupture of the synovia may mimic deep venous thrombosis clinically, this condition should be suspected if a prone view of the joint shows a well-demarcated area in the calf in continuity with a « hot » knee.

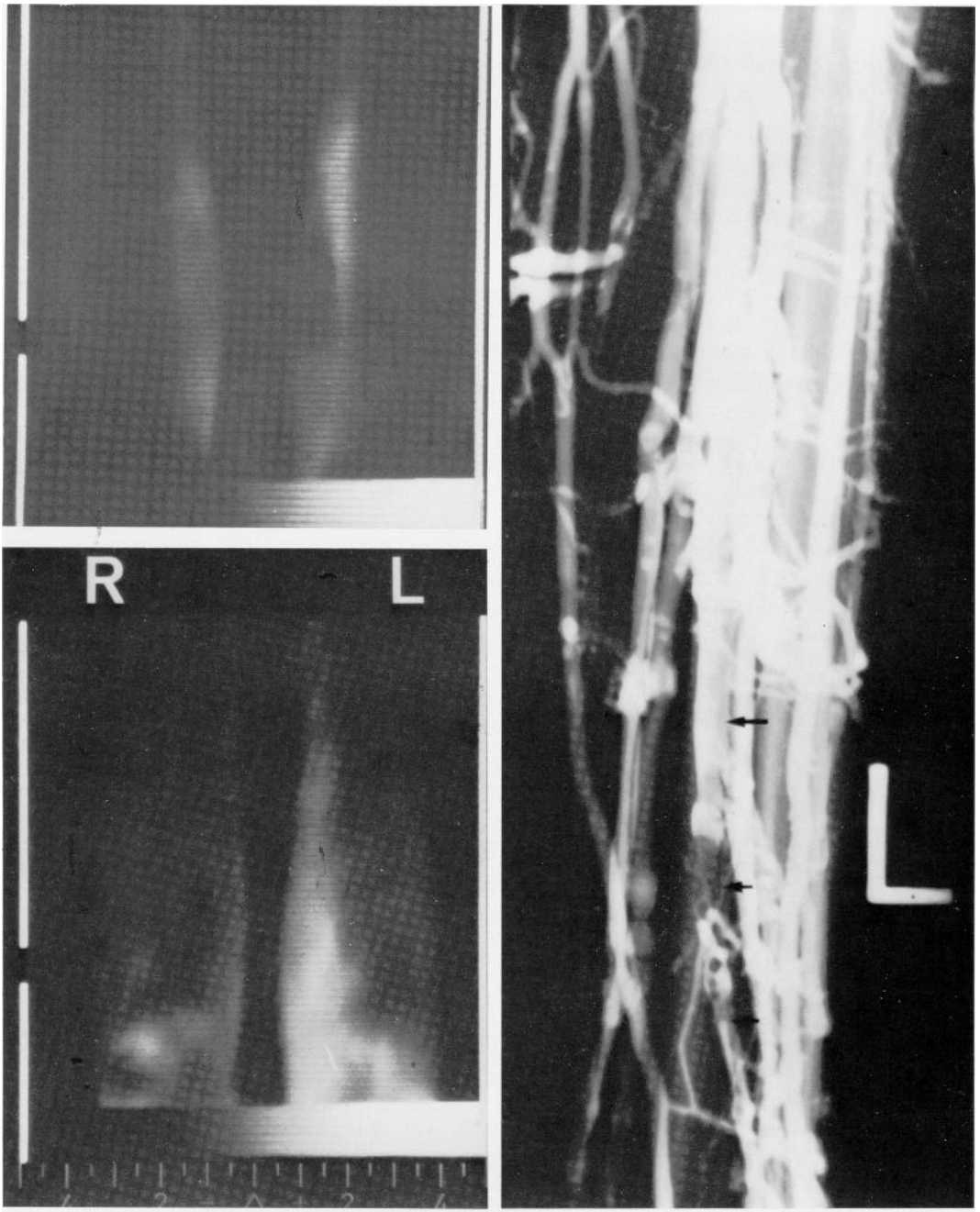


Fig. 18. A slight increase in calf temperature associated with thrombi in the posterior tibia1 vein. The thermograms were taken on consecutive days. Minor changes in a thermogram always indicate the necessity for the examination to be repeated. (See also Case B).

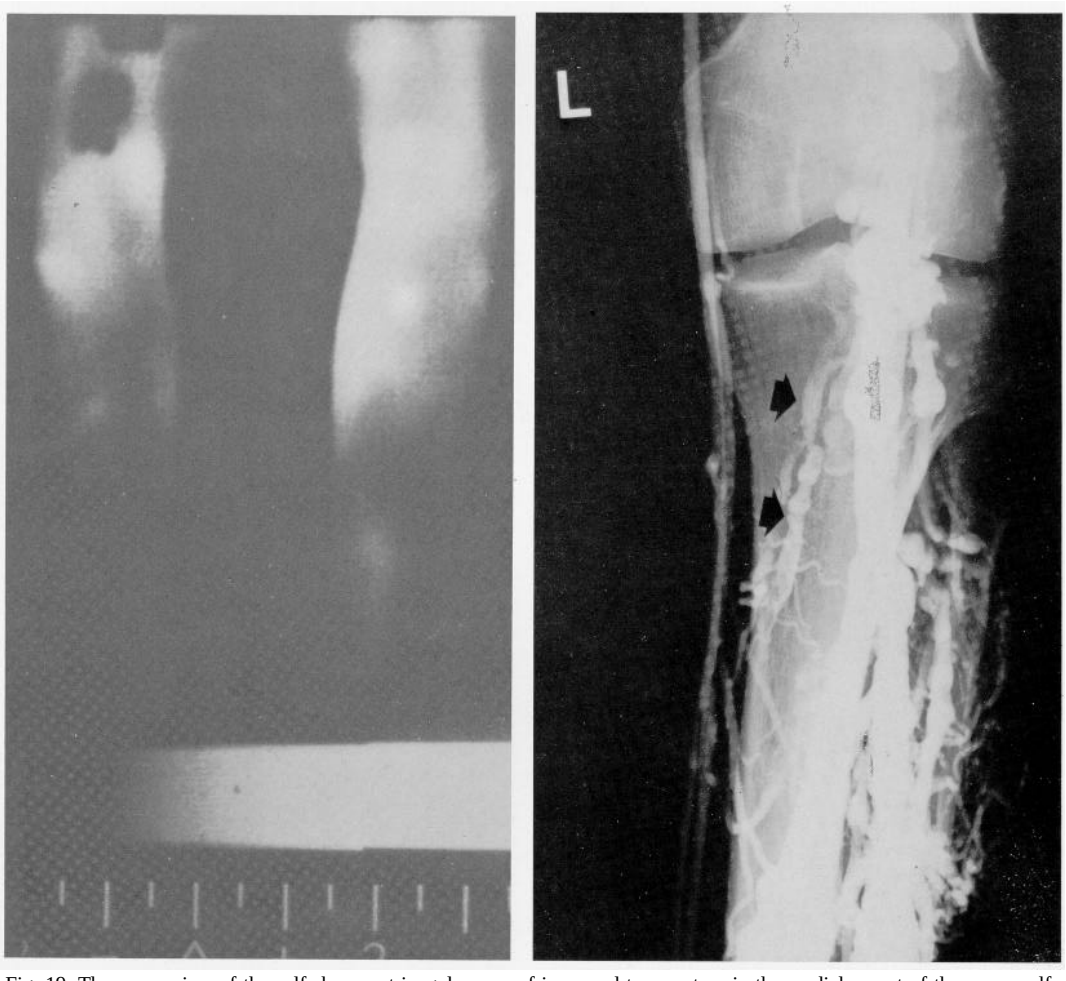


Fig. 19. The prone view of the calf shows a triangular area of increased temperature in the medial aspect of the upper calf. This appearance is typical of thrombosis isolated to the gastrocnemeal veins - see phlebograph. These appearances must be distinguished from rupture of a Bakers cyst in which the joint is also involved and the area ofincreased temperature has a clearly defined margin - see Fig. 35. (Presented by Dr. W. G. M. Ritchie).

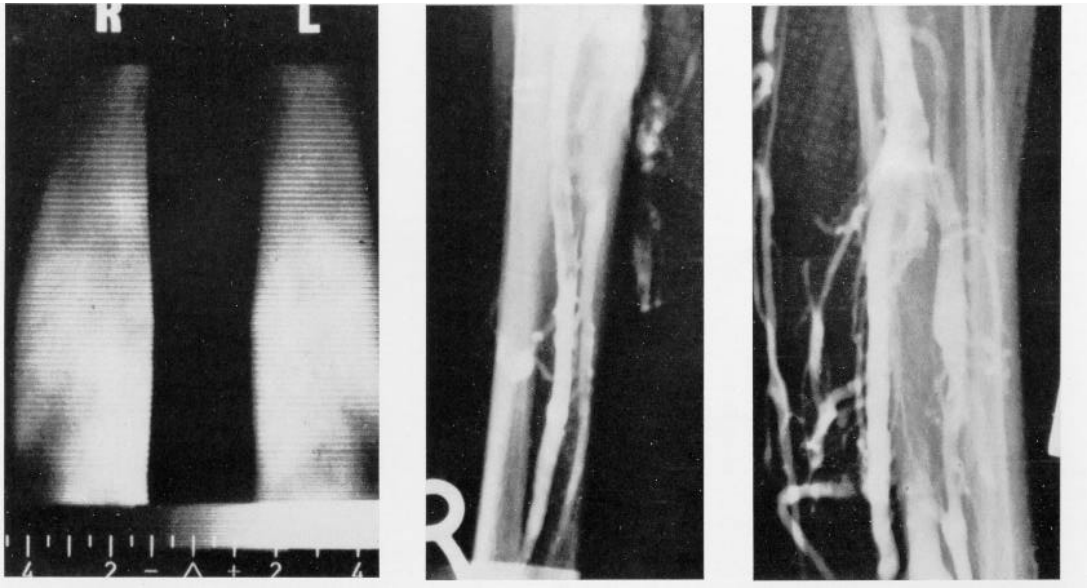


Fig 20 Bilateral calf vein thrombosis (supine view). The diffuse increase in calf temperature with a poorly defined margun is typical of recent DVT confined to the calf - see phlebographs.

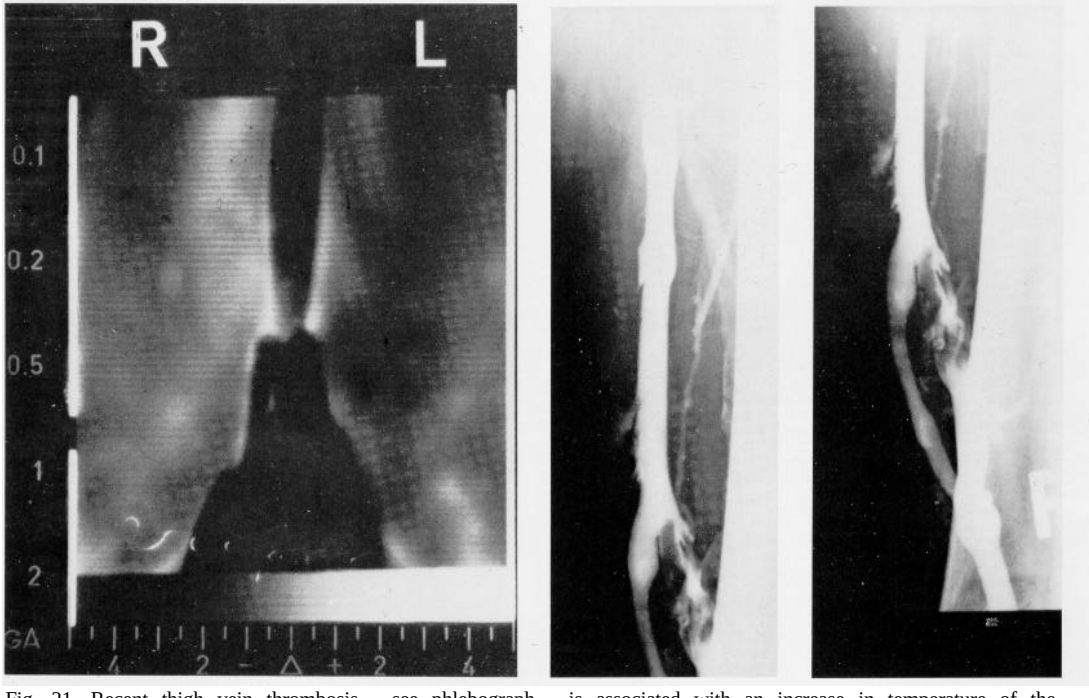


Fig. 21. Recent thigh vein thrombosis - see phlebograph - is associated with an increase in temperature of the medial aspect of the thigh. Typically the edge of the area is poorly defined.

Fig. 22. The thermogram shows a general increase in thigh temperature which may be associated with more proximal thrombi. This case of ileo-femoral thrombosis was demonstrated at autopsy.

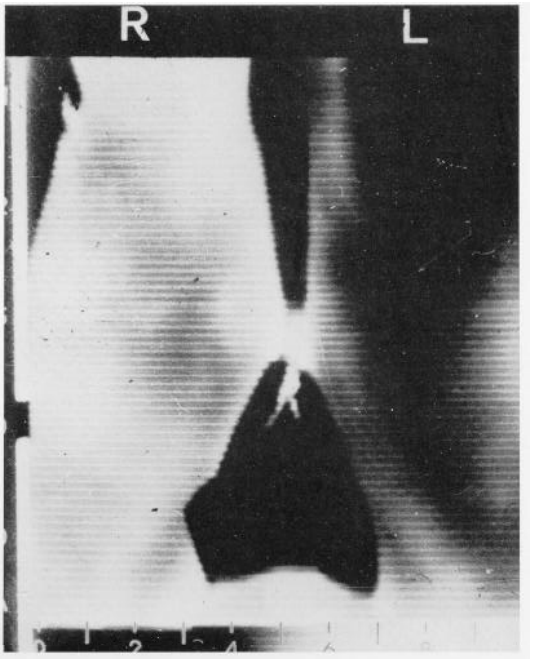
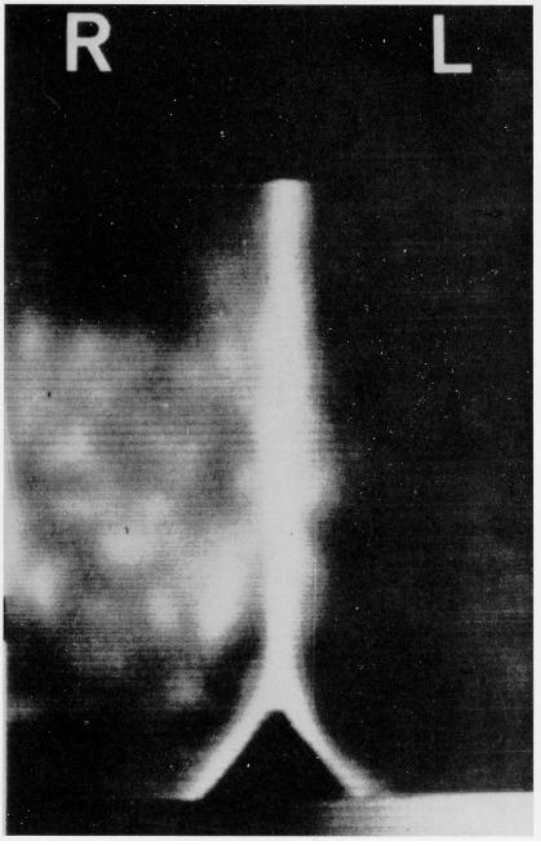


Fig. 23. The thermogram shows a more diffuse increase in thigh temperature associated with recent thigh vein thrombosis. The phlebograph shows thrombosis of deep femoral vein extending into the common femoral vein.



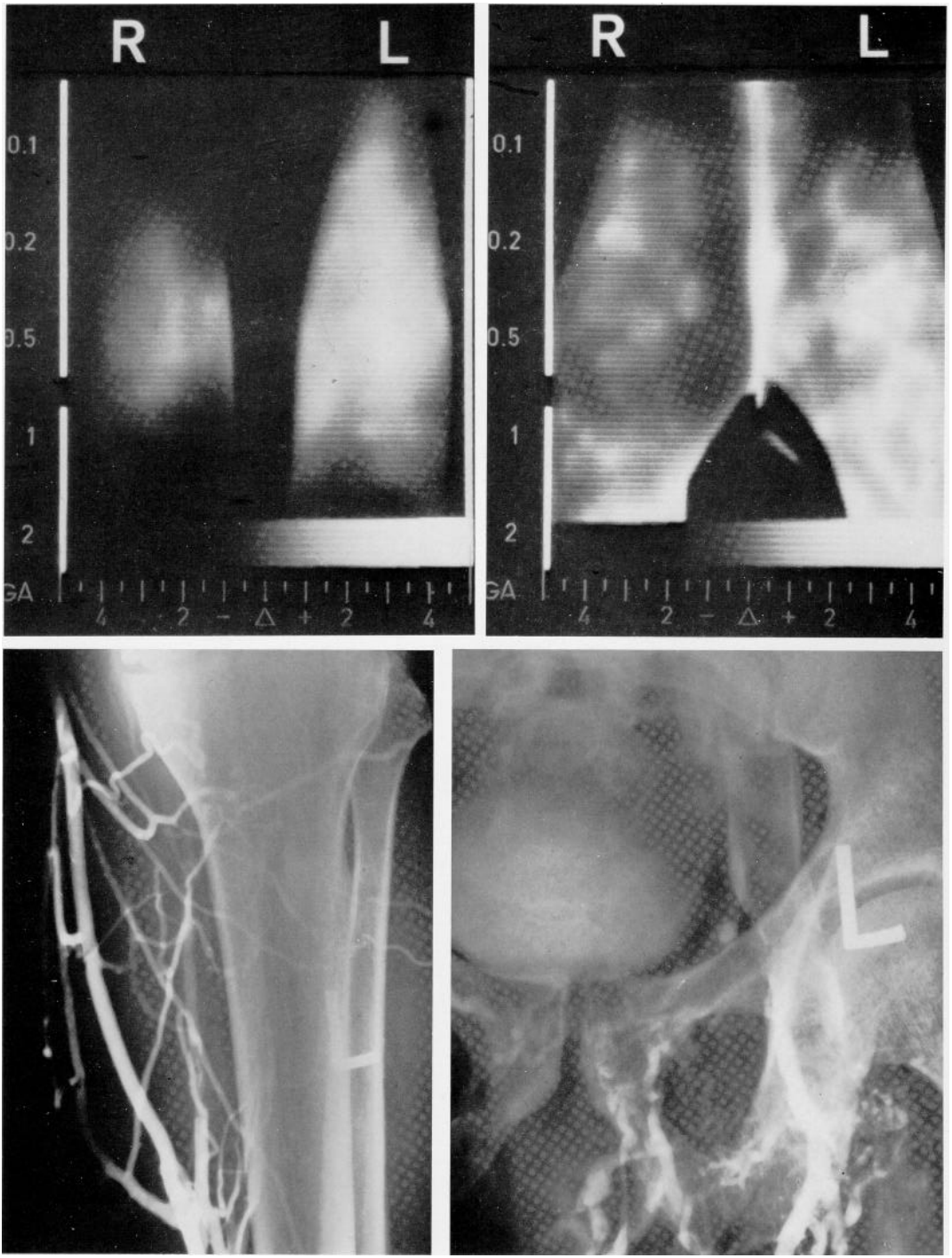


Fig 24. The thermograms show the typical appearance ofcalf and thigh vein thrombosis. Note the linear «hot-spots» extending from the medial thigh which suggests the presence of dilated superficial collateral veins. The phlebographs show thrombotic occlusion of the left calf and ileo-femoral veins with extensive collaterals.

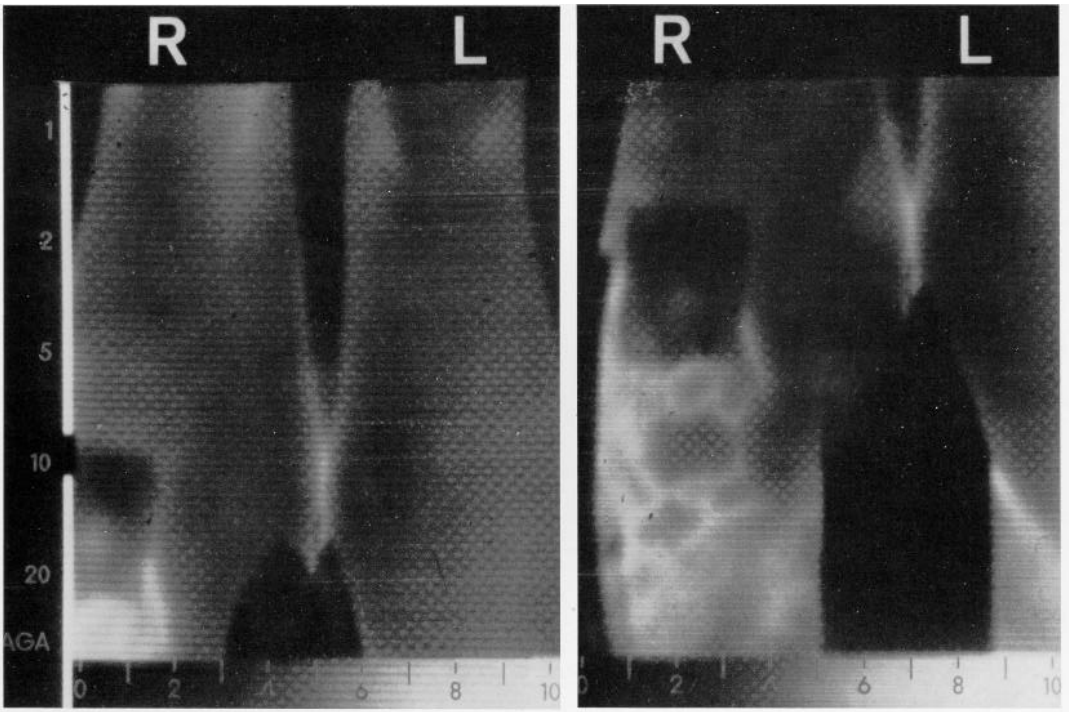


Fig. 25. Dilated veins over the site of the wound following hip surgery. These are always placed laterally and are not indicative of deep venous thrombosis.

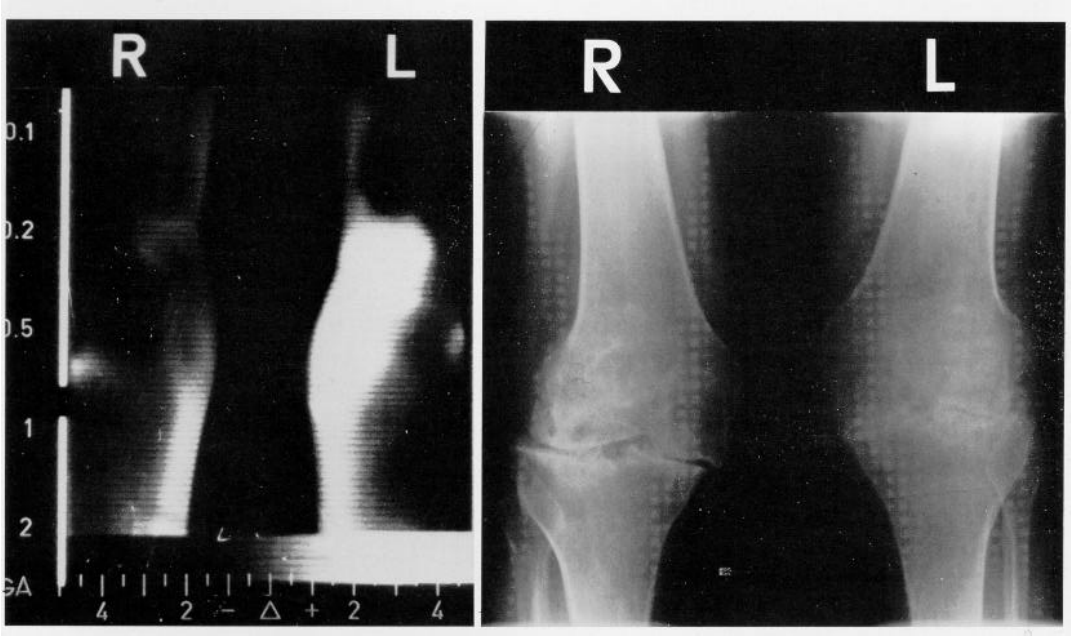


Fig. 26. The arthritidies - rheumatoid arthritis - note the area of increased temperature is sharply defined, and localised to the joint.

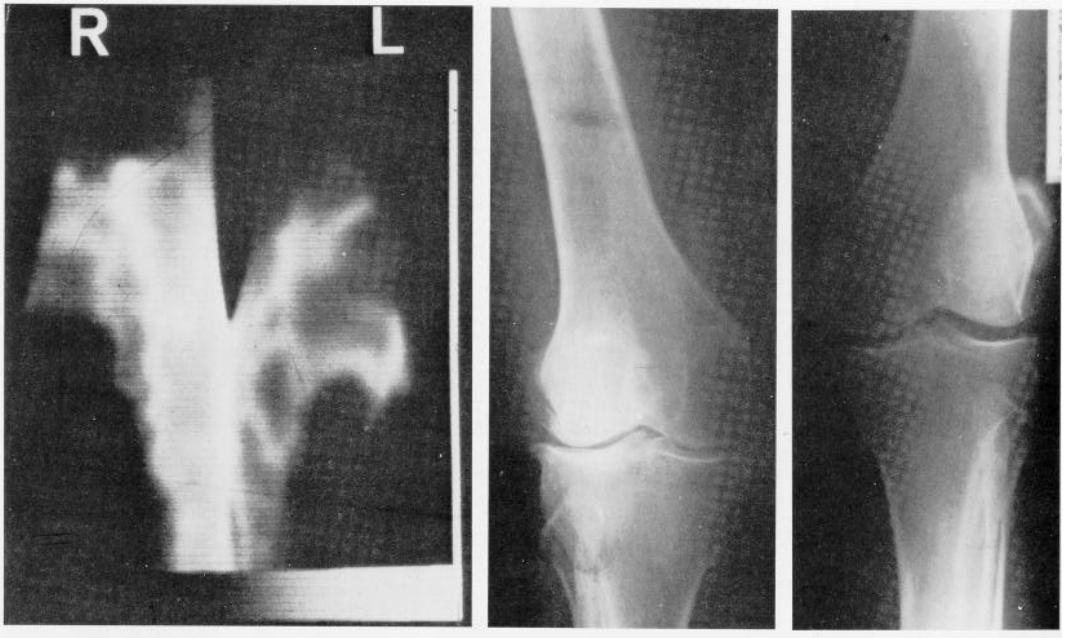


Fig. 27. The arthritidies - osteoarthritis producing an increase in the temperature with dilated veins localized to the knee joints.

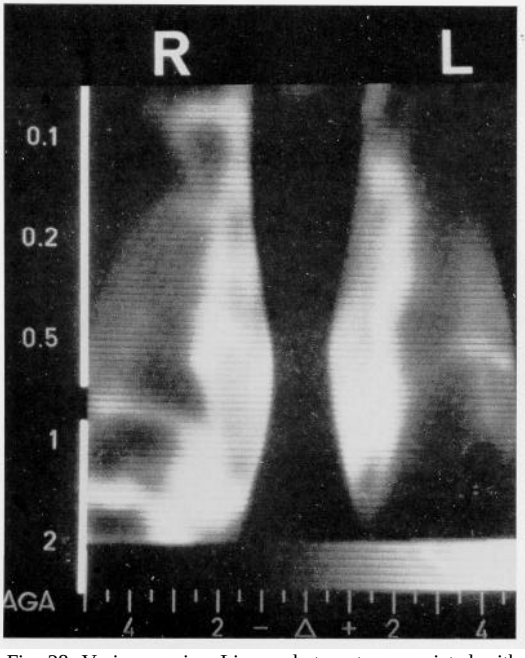


Fig. 28. Varicose veins. Linear «hot spots» associated with varicose veins of the calf - these are more evident when the patient stands; a position never adopted for examination for deep venous thrombosis.

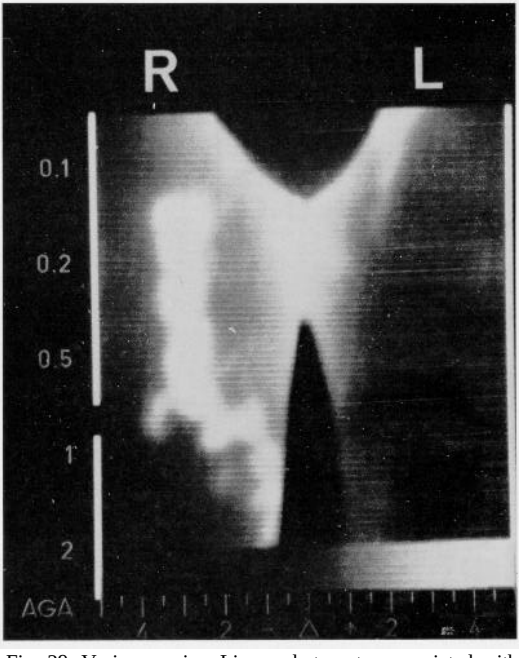


Fig. 29. Varicose veins. Linear «hot spots» associated with a saphenous varix - these are more evident when the patient stands; a position never adopted for examination for deep venous thrombosis.

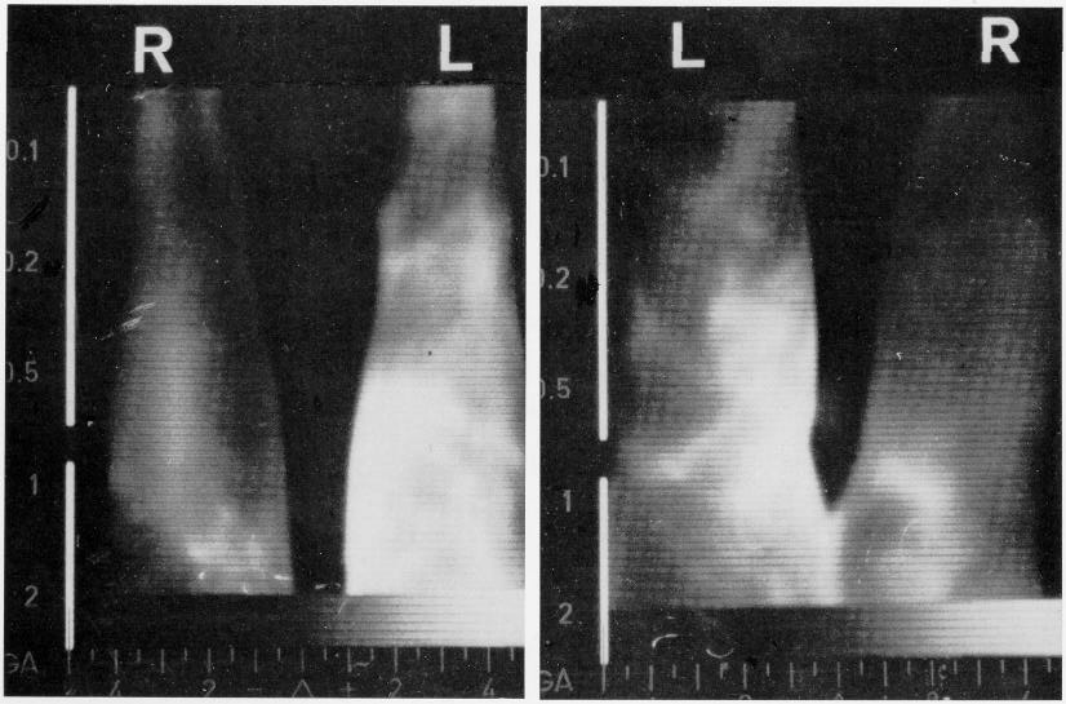


Fig. 30. Superfical thrombophlebitis: the supine (left) and prone (right) views of the calf show an area of Increased temperature witth a clearly defined edge. The serpiginous «hot-spot» is characteristic; however, the area of increased temperature is always greater than would be anticipated from clinical examination.

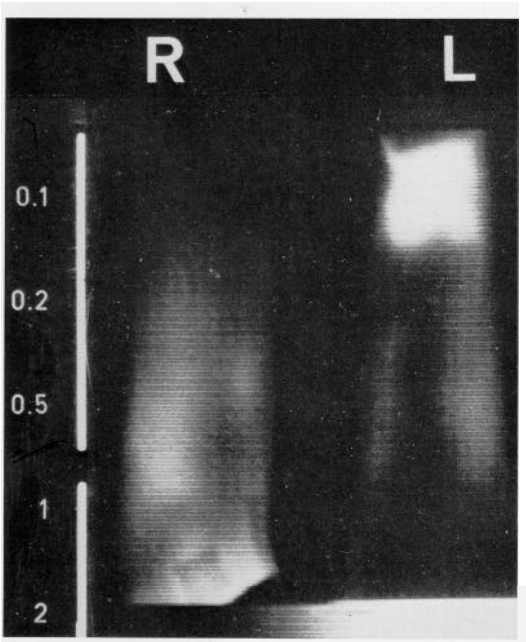


Fig. 31. **Cellulitis.** A localized, well demarcated «hot spot» associated with cellulitis just proximal to the ankle joint.

VARICOSE VEINS

Varicose veins may not be evident on the thermogram of the elevated leg. However, when not completely emptied by elevation, they appear as well-defined linear streaks usually in the long axis of the limb (Figs. 28 and 29). Any doubt is removed by examining the patient standing.

SUPERFICIAL THROMBOPHLEBITIS

Superficial thrombophlebitis produces a «white hot» clearly demarcated area on the thermogram much larger than the clinical lesion which stands out in marked contrast to the normal cool tissues of the leg (Fig. 30).

INFLAMMATORY CONDITIONS OF THE SKIN

Inflammatory skin conditions invariably produce well-defined «hot spots» on the thermogram which are much larger than would be expected from clinical examination. The

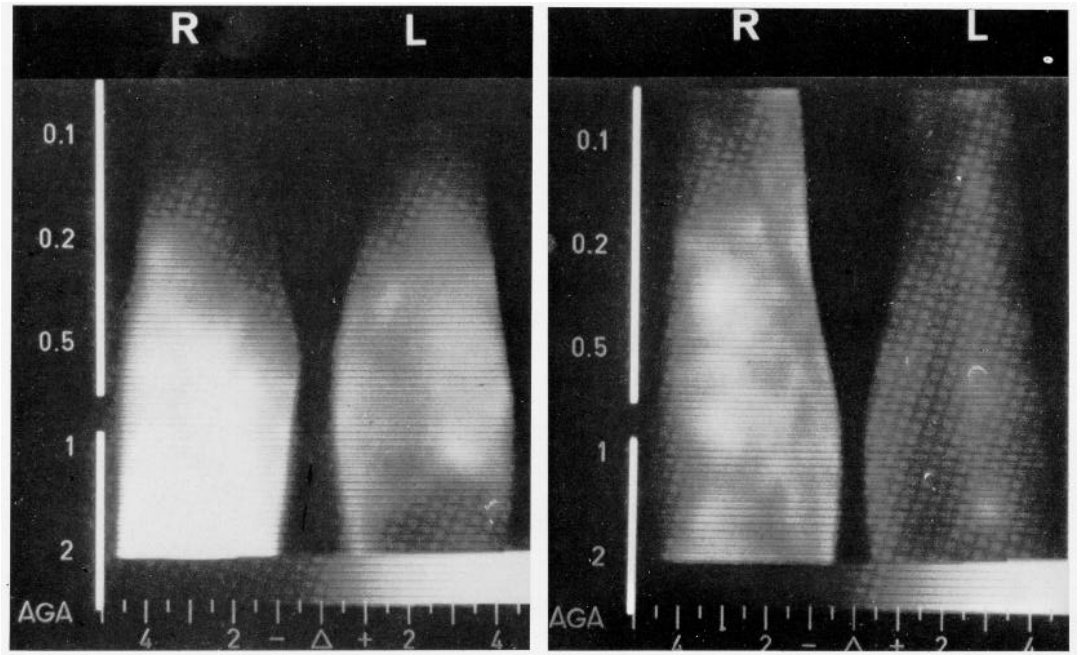


Fig. 32. Thermogram on left shows trauma to the right calf producing an extensive area of increased temperature in the right calf. There is a clearly marked edge to the area distally. One day later. Note the rapid resolution wich commonly occurs with such lesions (right).

temperature of the lesion may be three or four degrees higher than normal surrounding tissue from which it stands out in marked contrast (Fig. 31).

TRAUMATIC CONDITIONS OF THE LIMB: HAEMATOMA AND FRACTURE

Small areas of trauma produce discrete, well-defined «hot spots» on the thermogram which are indistinguishable from inflammatory conditions. More extensive trauma may produce a «white hot» calf or thigh. However, in such cases the upper or lower border is usually well-defined (Fig. 32). (When DVT is suspected to complicate fractures of the long bones of the limb, it will be apparent that phlebography should be used to confirm or refute the diagnosis).

DISEASES OF BONE: OSTEOMYELITIS, TUMOR, PAGET'S DISEASE

Osteomyelitis and tumor (Fig. 33) produce well-defined «hot spots» on the thermogram which stand out in marked contrast to the surrounding, cooler areas. In contrast, active Paget's disease (Fig. 34) may produce a «white hot» thermogram. A plain x-ray indicates the correct diagnosis.

BAKERS CYST

Rupture of a Bakers cyst appears as a clearly demarcated «hot spots» in and inferior to the popliteal fossa (Fig. 35) and, as would be expected, is in continuity with changes in the joint.

LIMB PARALYSIS AND PERIPHERAL VASCULAR DISEASE

Unless paralysis or peripheral vascular disease is bilateral, the involved limb is always at lower temperature than the contralateral side (Fig. 36). This may lead to erroneous interpretation of the thermogram; if only increase in temperature is looked for the normal limb may be considered to have a deep venous thrombosis. However, the temperature of the

Fig. 33. Bone tumor. An increase in calf temperature produced by bone tumor. This condition is apparent on x-ray of the bone.

normal limb is uniform and the cool tibia and patella are retained. Peripheral vascular disease is usually recognized by the «white hot» line (area of hyperaemia) which is present between the proximal normal area and the area of distal ischaemia (Fig. 37). Sympathectomy may produce bizarre thermographic appearances (Fig. 38).

From the above description it will be understood that only high quality thermograms showing the greatest possible number of greytones should be interpreted. Calf and thigh must be examined separately, ***never*** together, and the image obtained must be as large as possible.

THE POSTPHLEBITIC SYNDROME (CHRONIC VENOUS INSUFFICIENCY)

Thermography is of value in the postphlebitic syndrome in two ways. It may be used as an aid to diagnosis in symptomatic patients and also identities such patients even when

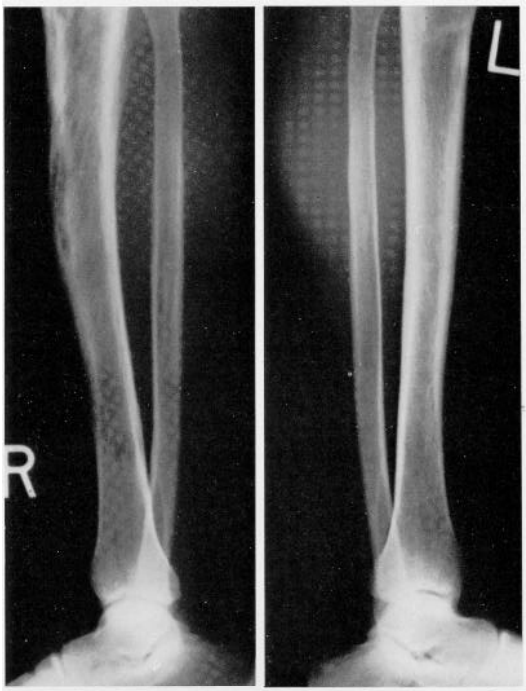
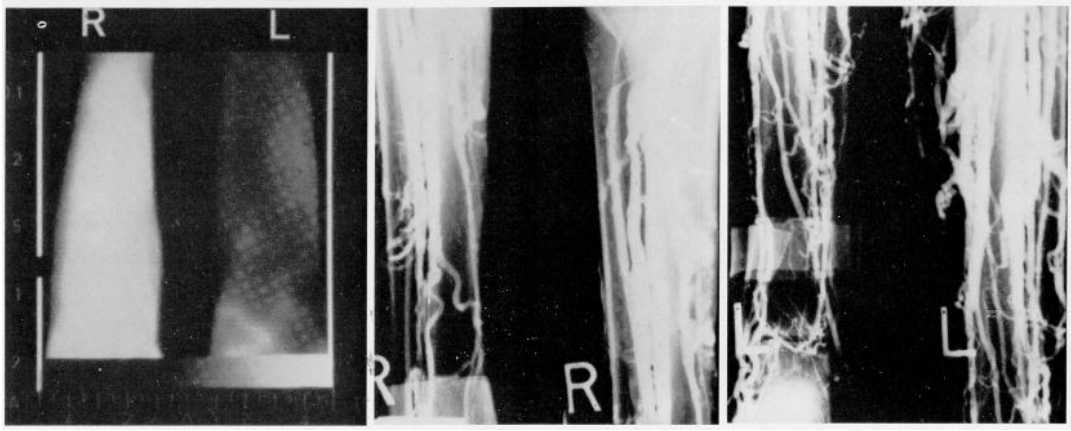


Fig. 34. Paget's Disease. The «white hot» thermogram below is illustrative of active Pagest's Disease - this condition may mimic extensive deep venous thrombosis of the calf but is simply differentiated clinically and radiologically. Note the normal phlebograph of the calves.



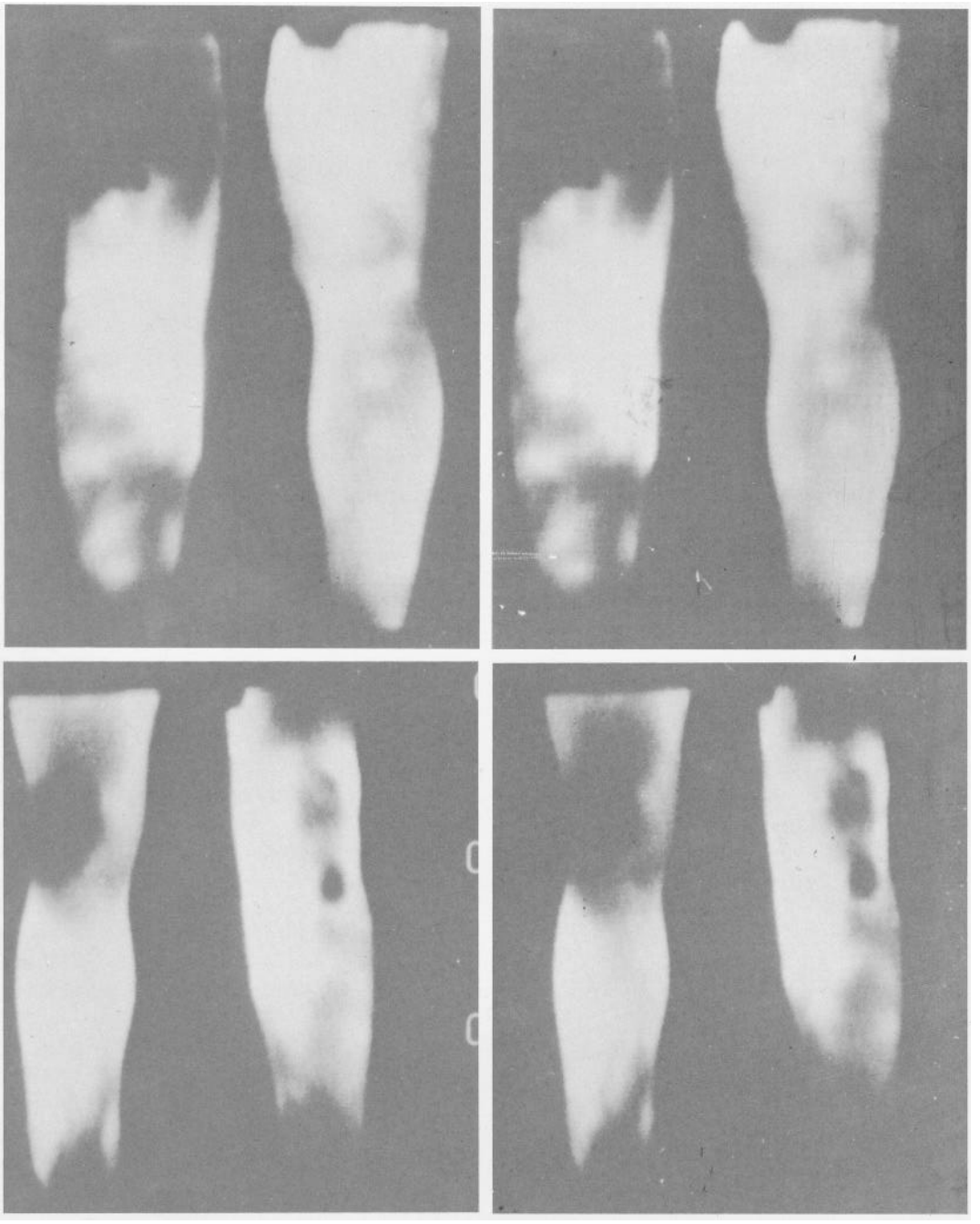


Fig. 35. Ruptured Bakers Cyst. The supine view (top) shows an increase in temperature confined to the joint. The prone view (bottom) also demonstrates the increase in Joint temperature which is in continuity with a sharply defined area of increased temperature in the upper calf. Compare with Figure 19. (Presented by W. G. M. Ritchie).

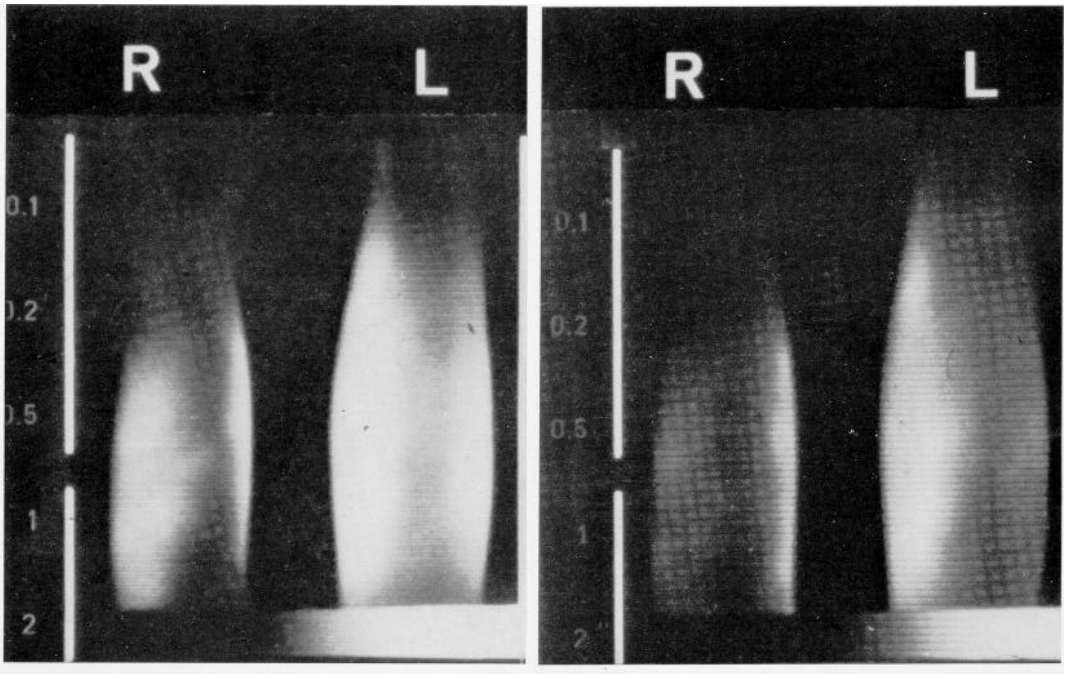


Fig. 36. Paresis of the right leg: the temperature of the normal left leg is slightly higher than that of the right side. Note, however, that the cool tibial area is retained. The thermogram on the right was obtained after further cooling of the limbs by continued exposure.

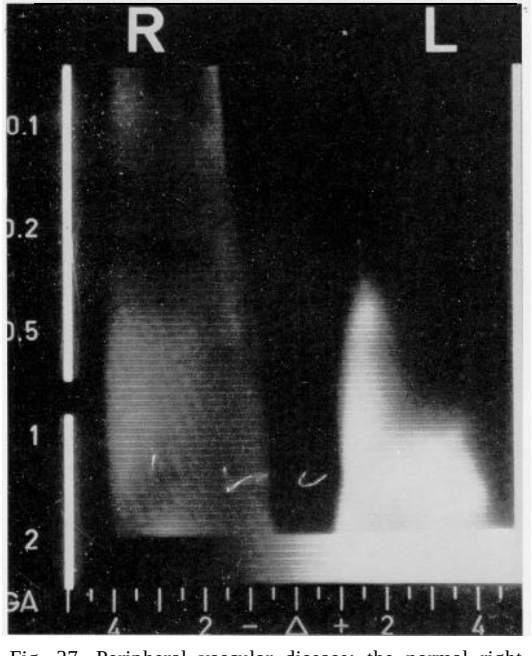


Fig. 37. Peripheral vascular disease: the normal right leg is warmer than the left side. On the left leg the hot spot proximal to the area of distal ischaemia is typical.

they are asymptomatic. These cases are recognized to be at high risk of developing a deep venous thrombosis post-operatively.

The unreliability of clinical signs and symptoms of recent deep venous thrombosis have already been noted. The disease is frequently missed in asymptomatic patients and a false positive diagnosis is common in patients with symptoms. Particular difficulty may arise when patients have chronic venous insufficiency, the postphlebitic syndrome. Many of these patients remain asymptomatic for some years after which symptoms may appear acutely giving rise to the suspicion of recurrent acute thrombosis. In such cases the thermographic appearances appear to depend on the venous drainage of the limb. When venous drainage is adequate, the thermogram of the resting patient may show a normal appearance or only a few discrete hot spots from dilated varicosities (Fig. 39). If the venous drainage is inadequate (this is always associated with a symptomatic limb), the temperature of the whole limb, in particular the calf, is elevated

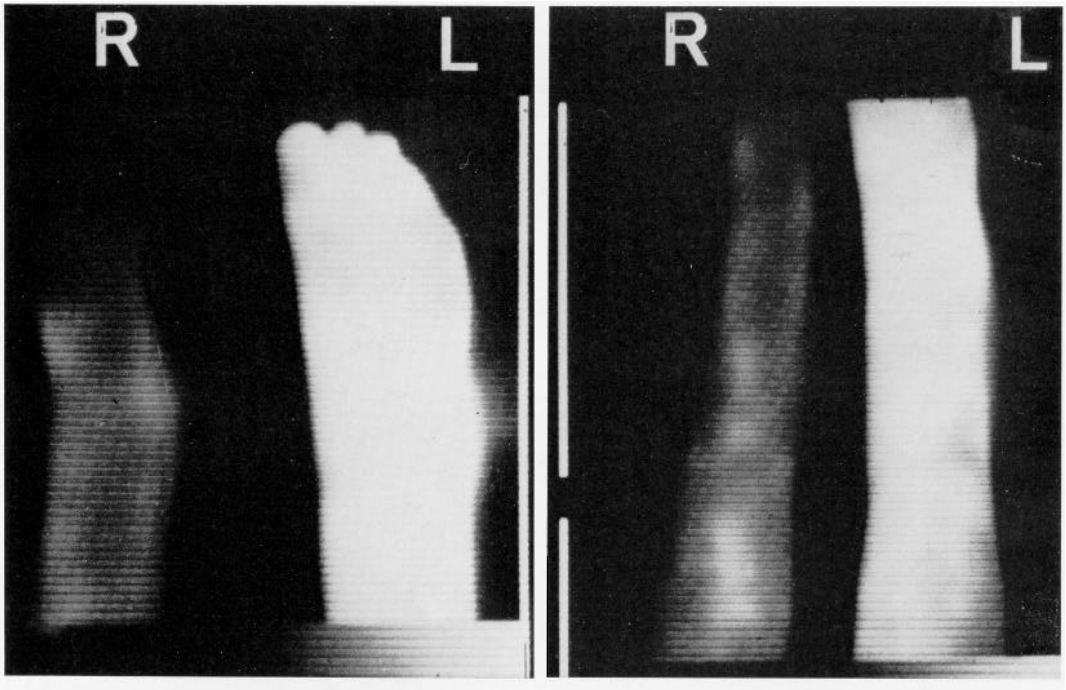


Fig. 38. Sympathectomy produces a generalized increase in limb temperature

but the pattern is blotchy (Fig. 40) lacking the uniformity found with recent thrombosis. If chronic venous insufficiency is suspected but the thermography is normal, the diagnosis will be shown by an «after exercise» thermogram. For this test, the patient is asked to perform gentle leg exercises, for example gentle running on the spot for a few minutes, and a thermogram is immediately taken in the usual, supine, legs elevated position. Normally, exercise elevates the temperature of the legs, but the thermographic features of normality, in particular the cool subcutaneous border of the tibia, are maintained and no linear hot spots are evident (Fig. 41). In contrast, when chronic venous insufficiency is present, the thermogram after exercise shows a bizarre arrangement of linear hot spots superimposed on a background of raised leg temperature (Fig. 42). The usefulness of this test is assessing the risk of developing deep venous thrombosis after surgery has been shown.[34] In a group of general surgical patients, ninety percent of patients showing a positive «after exercise» thermogram deve-

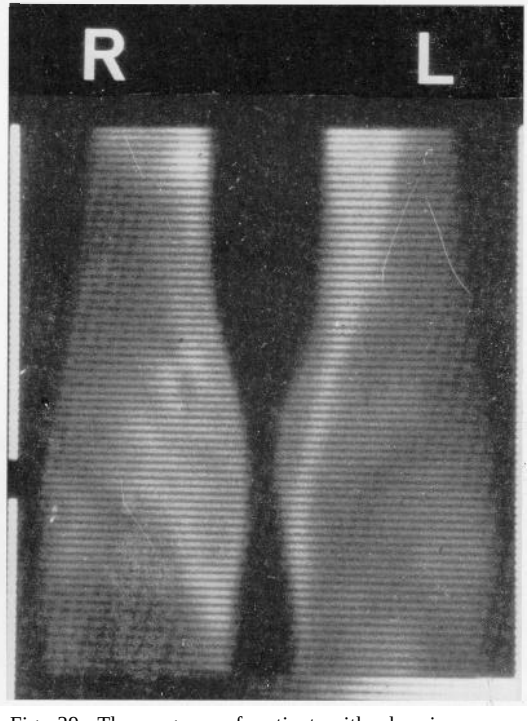


Fig. 39. Thermogram of patient with chronic venous insufficiency taken at rest.

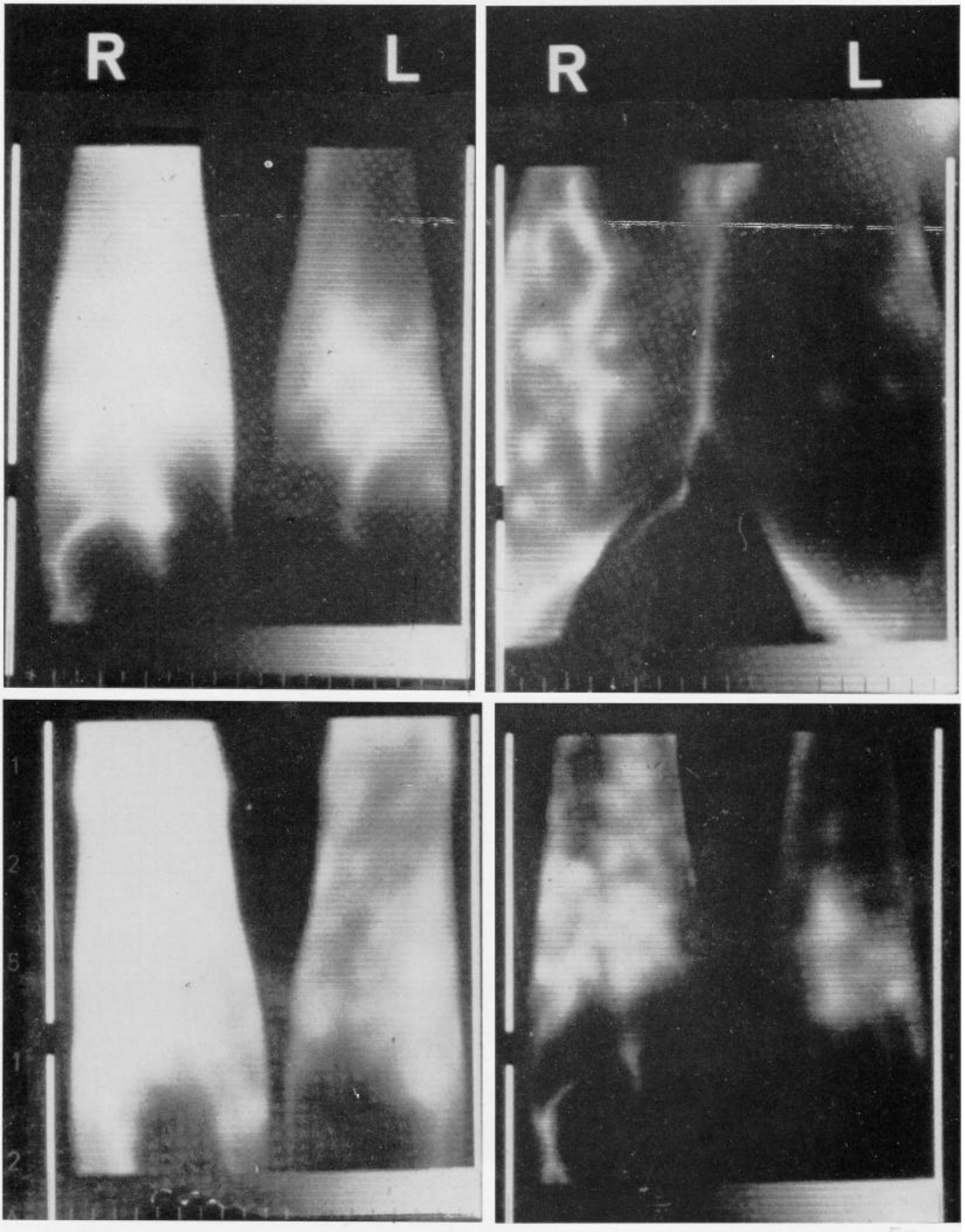
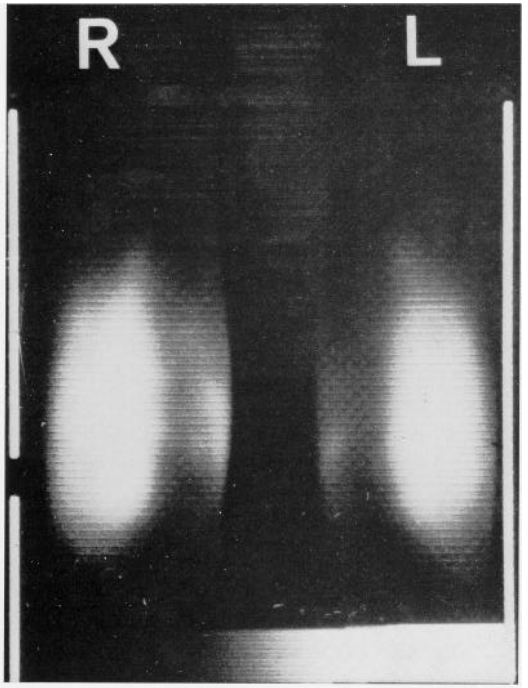


Fig. 40. Symptomatic chronic venous insufficiency of both legs - the left leg was swollen and indurated while the right appeared normal. There is a marked generalized increase in the temperature of the right side, but the appearances are uneven and dilated veins are apparent proximally. The thermogram on the lower right was taken after artificial cooling of the limb.



loped a postoperative leg-vein thrombus while this complication was noted in only ten percent of cases with a normal «after exercise» thermogram.

It should be noted that oedema of the leg from other causes such as cardiac failure (Fig. 43) or lymphoedema (Fig. 44) are usually associated with a cool thermogram unless these conditions are complicated by deep venous thrombosis. One observer has described cases with «warm » oedematous legs in which phlebography did not demonstrate thrombosis in the deep veins. However, thermographic appearances in these cases were not typical of DVT.

Fig. 41. The normal «after exercise» thermogram; note the increase in calf muscle temperature and retention of the longitudinal band of the cooler tibia.

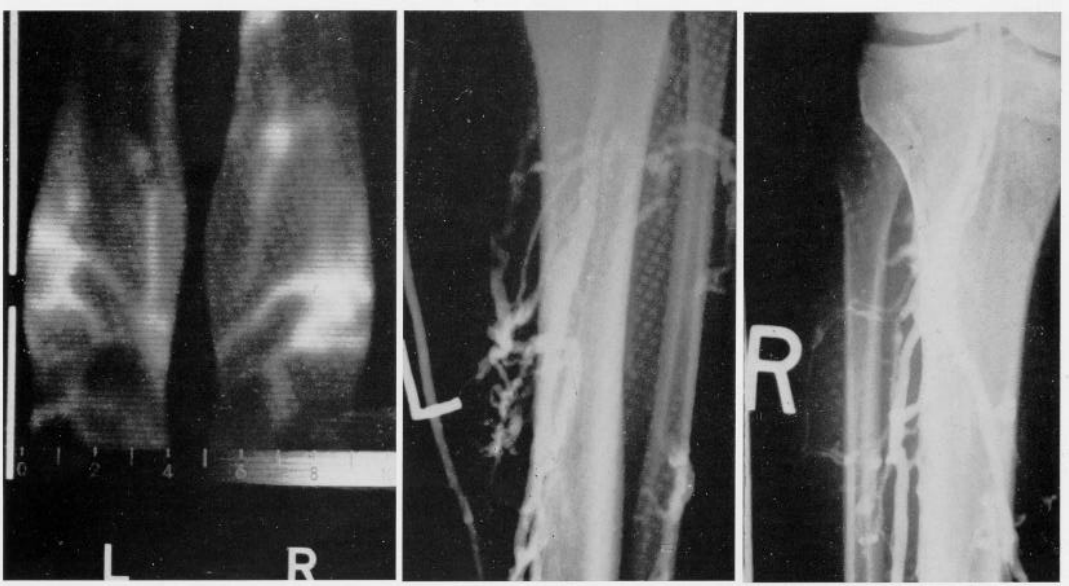


Fig. 42. «After exercise» thermogram in asymptomatic chronic venous insufficiency; note the haphazard arrangement of dilated collateral veins. The resting thermogram of this patient is shown in Fig. 39. The phlebo graph shows the appearances of chronic venous insufficiency.

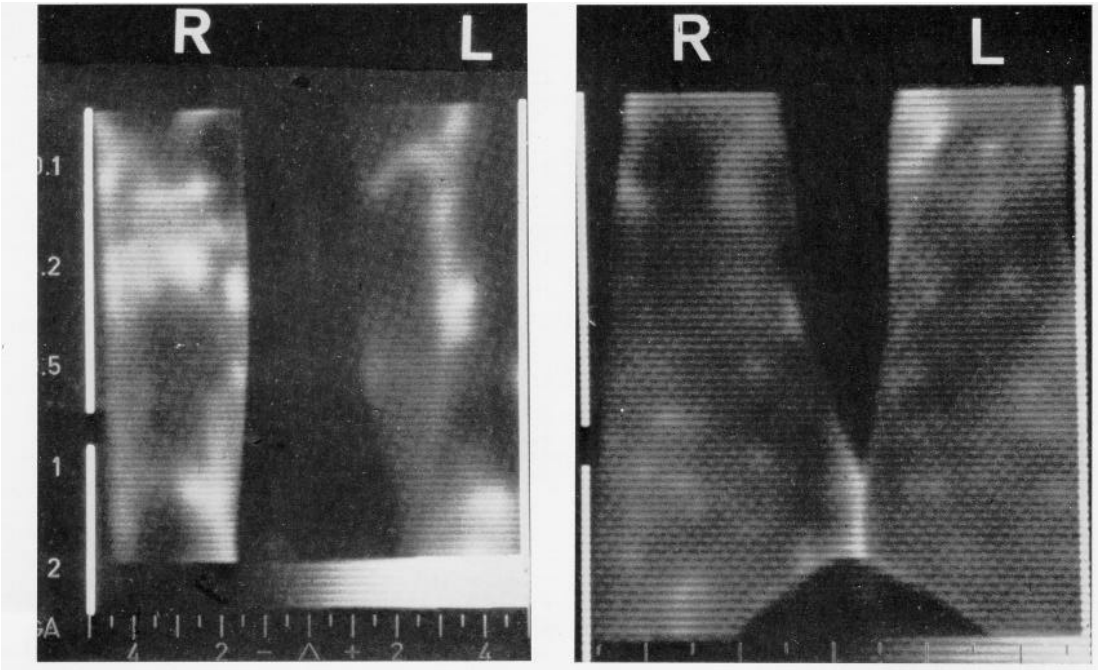


Fig. 43. Cardiac oedema uncomplicated by DVT showing discrete hot spots due to venous congestion on an overall cool background.

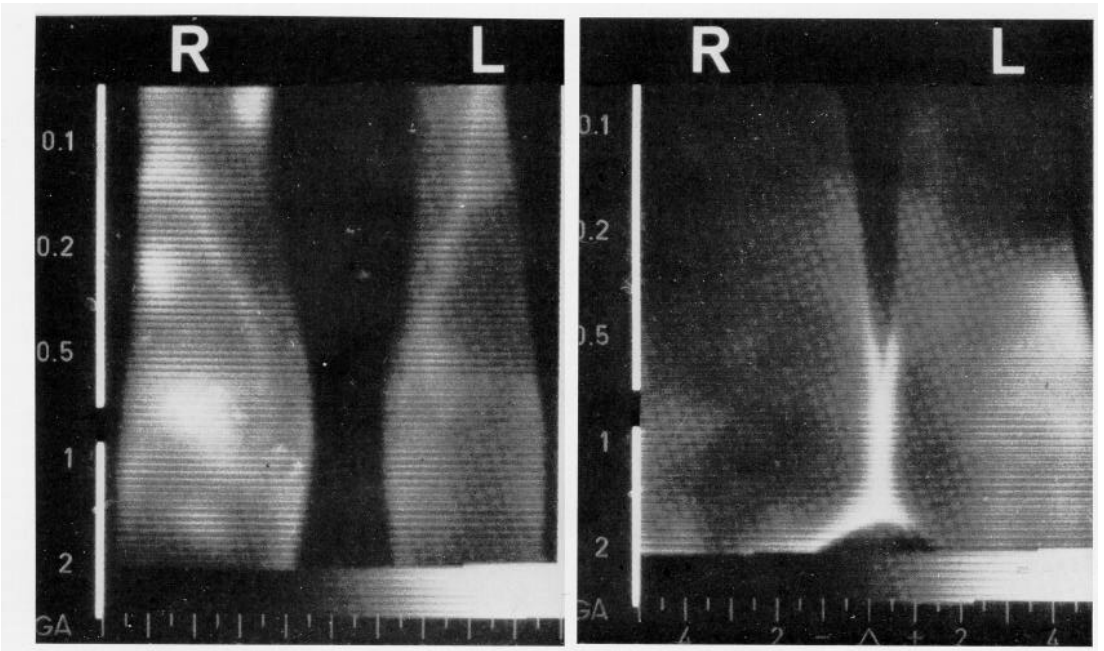


Fig. 44. Left sided lymphoedema: the leg is generally cool with a few discrete hot spots

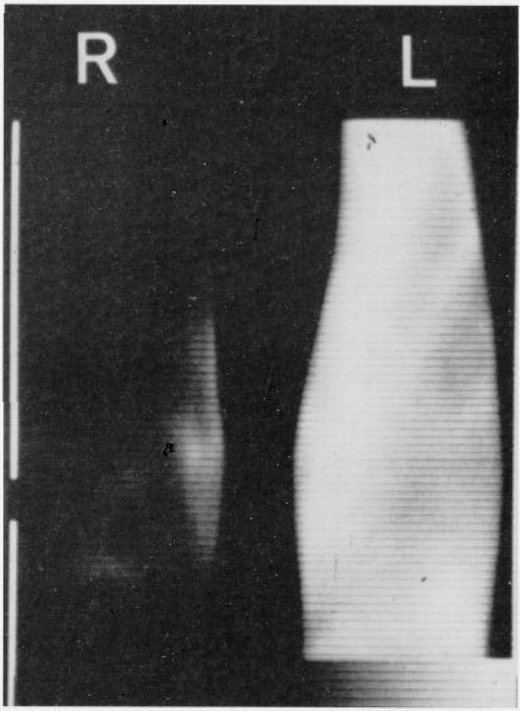
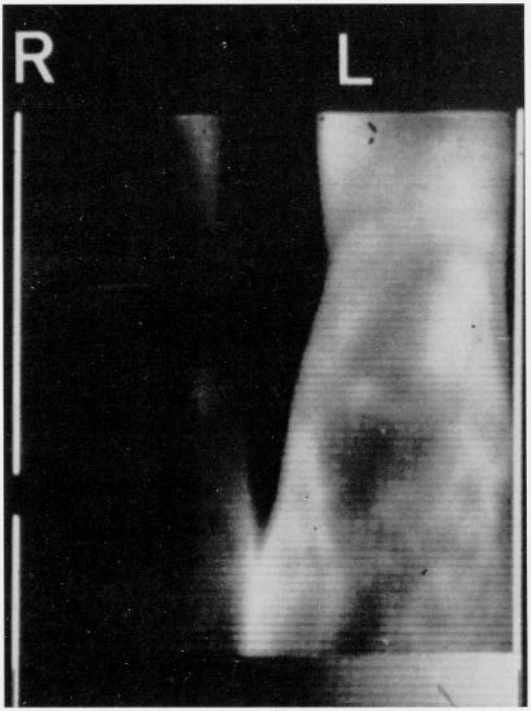
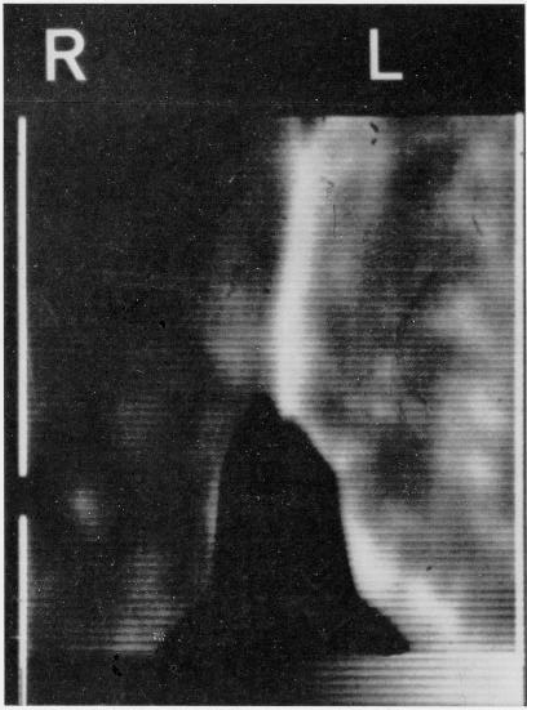
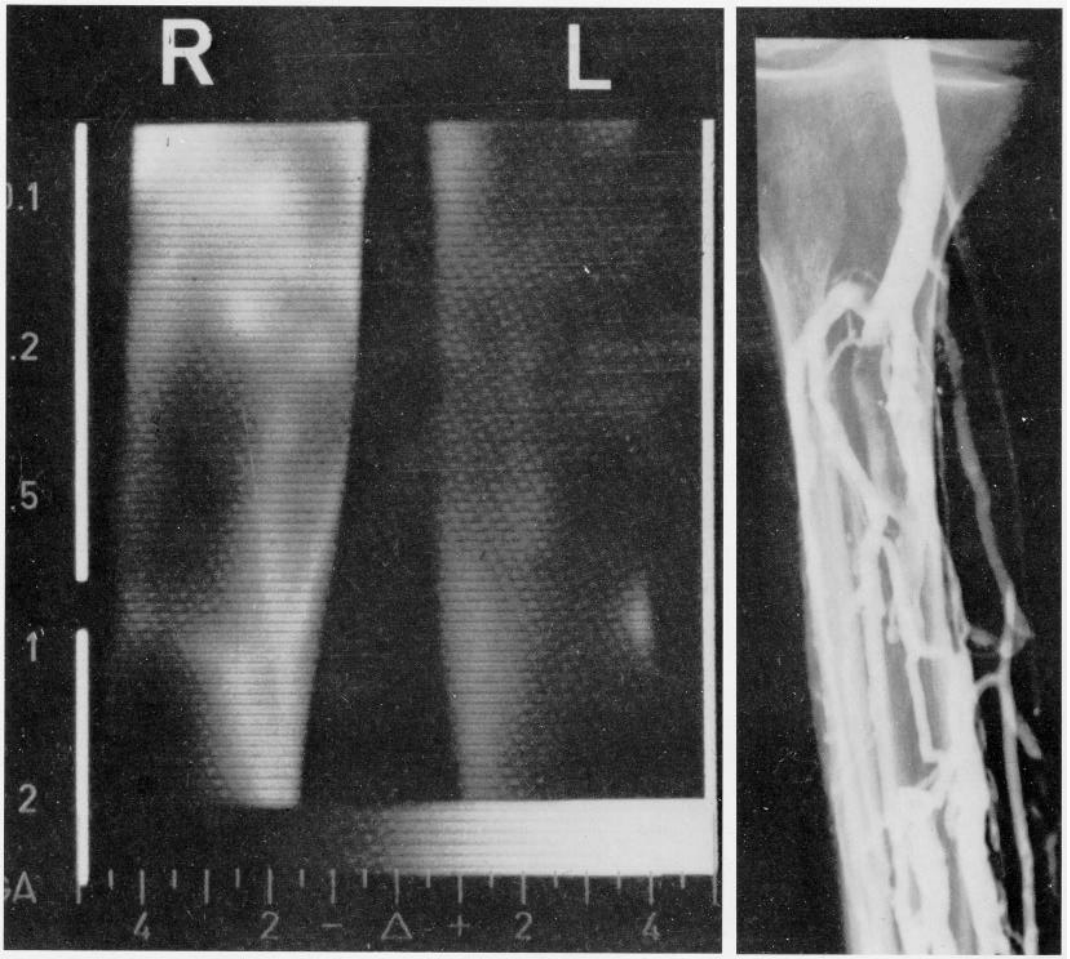


Fig. 45. Thermogram of 64 year old male presenting with chest pain and dyspnoea following a period of three weeks bed-rest for pain in the left foot and calf. This demonstrates the presence of a whole leg thrombosis. Pulmonary embolism was shown by perfusion scanning.

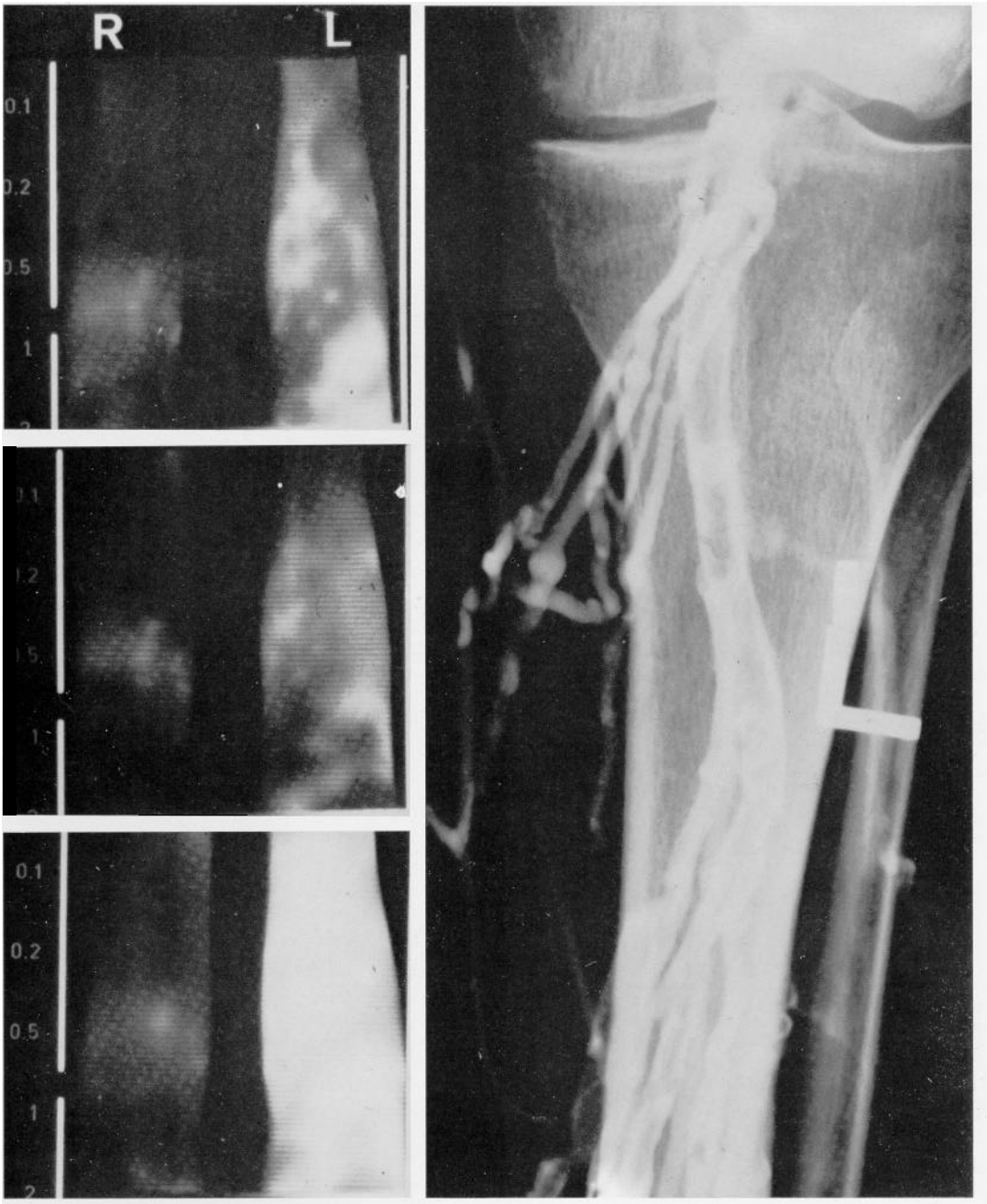




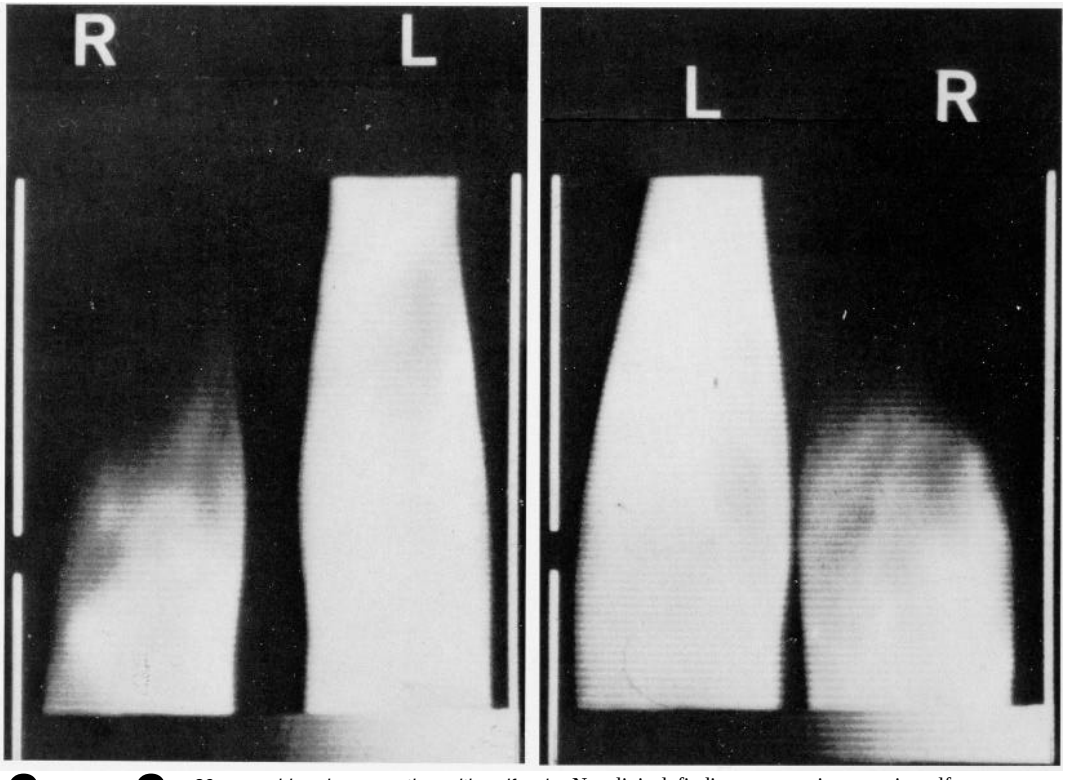
IX Case Presentations



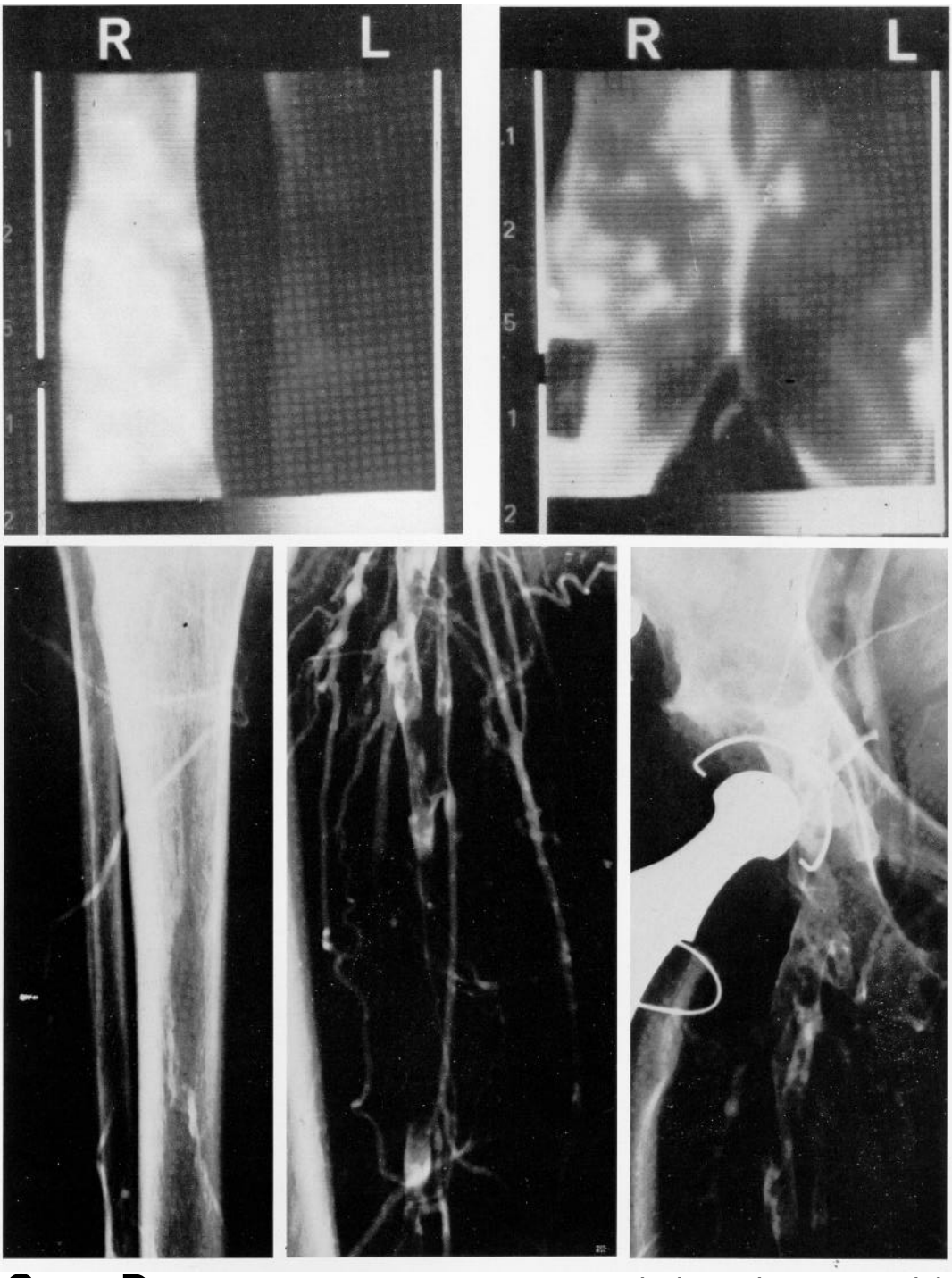
Case A. *70 year old patient prior to* sugery. The thermogram shows an increase in the temperature of the proximal and medial aspects of the leg on which is superimposed linear hot spots. The phlebograph shows thrombotic occlusion of the proximal segment of one of paired posterior tibia1 veins. Patient had rested in bed for ten days prior to admission to hospital.



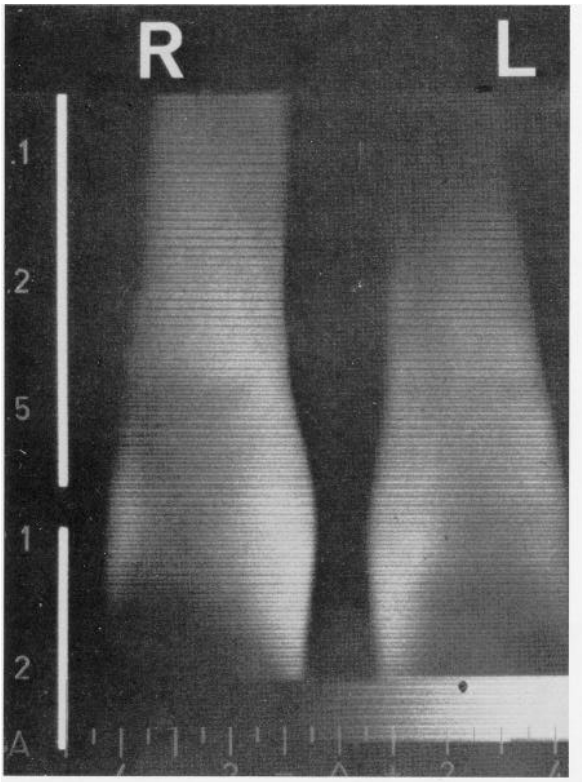
Case B. *74 year old female after major surgery.* Top thermogram: first postoperative day: generalized increase in temperature of left calf with a random distrtbution of cooler and warmer areas. Most likely dragnosts considered to be chronic venous insufficiency. Middle thermogram: fifth postoperative day: generalized increase in left calf temperature persists; less demarcation between cool and warmer areas. Phlebography shows extensive calf vein thrombosis. Bottom thermogram: twelfth postoperative day: marked thermographic changes suggesting propagation to the thigh veins despite heparinization. The phlebograph shows extensive fresh thrombi in the calf veins.



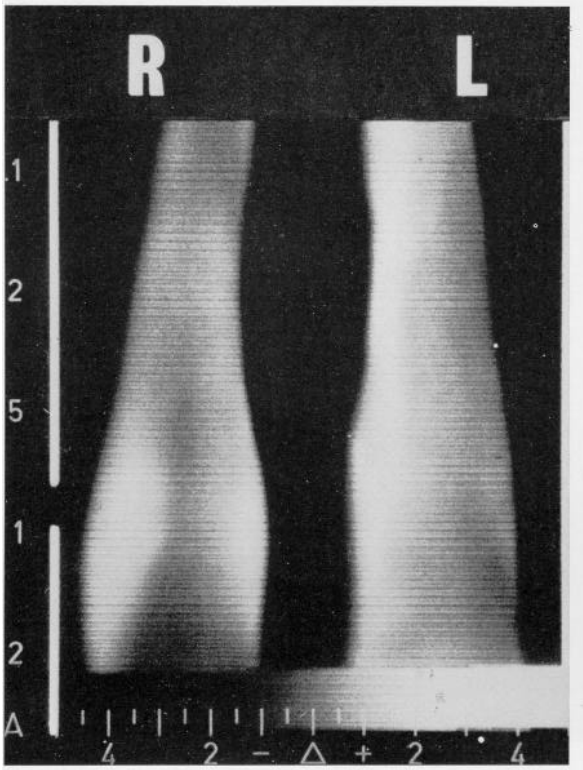
Case C. *30 year old male presenting with calf pain.* No clinical findings except increase in calf temperature and an oral temperature of 38.9°C. Thermography shows marked increase in temperature of the whole calf on supine (left) and prone (right) views. Twenty-four hours later extensive cellulitis of the calf was apparent. However, the thermographic appearance might have been due to extensive calf vein thrombosis. Thus in the absence of clinical signs phlebographic examination would have been indicated.

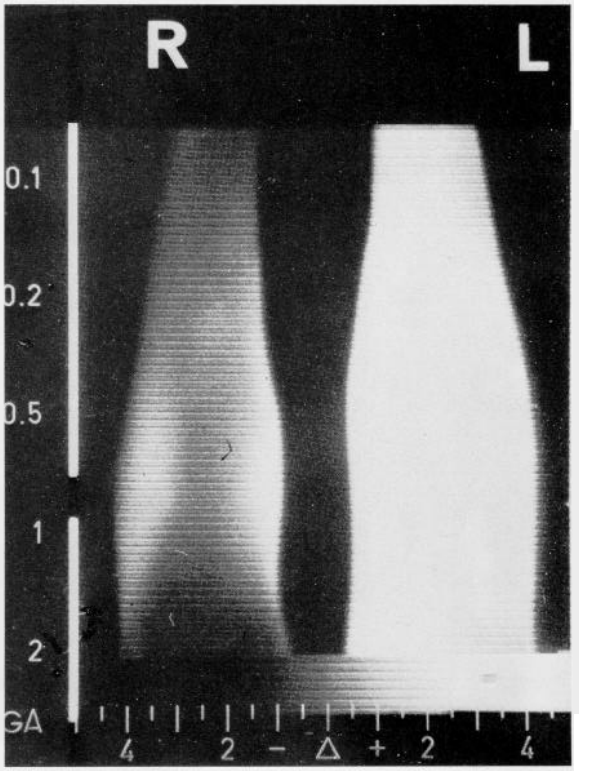


Case D *63 year old patient two days after total hip replacement.* The thermographrc appearances which show an increase in the whole leg are typical of a whole leg-vein thrombosis. Note the blotchy appearance of the calf suggesting recent DVT superimposed on chronic venous insufficiency. The phlebograph shows the appearances of recent thrombosis involving the calf and thigh of the right leg in continuity.



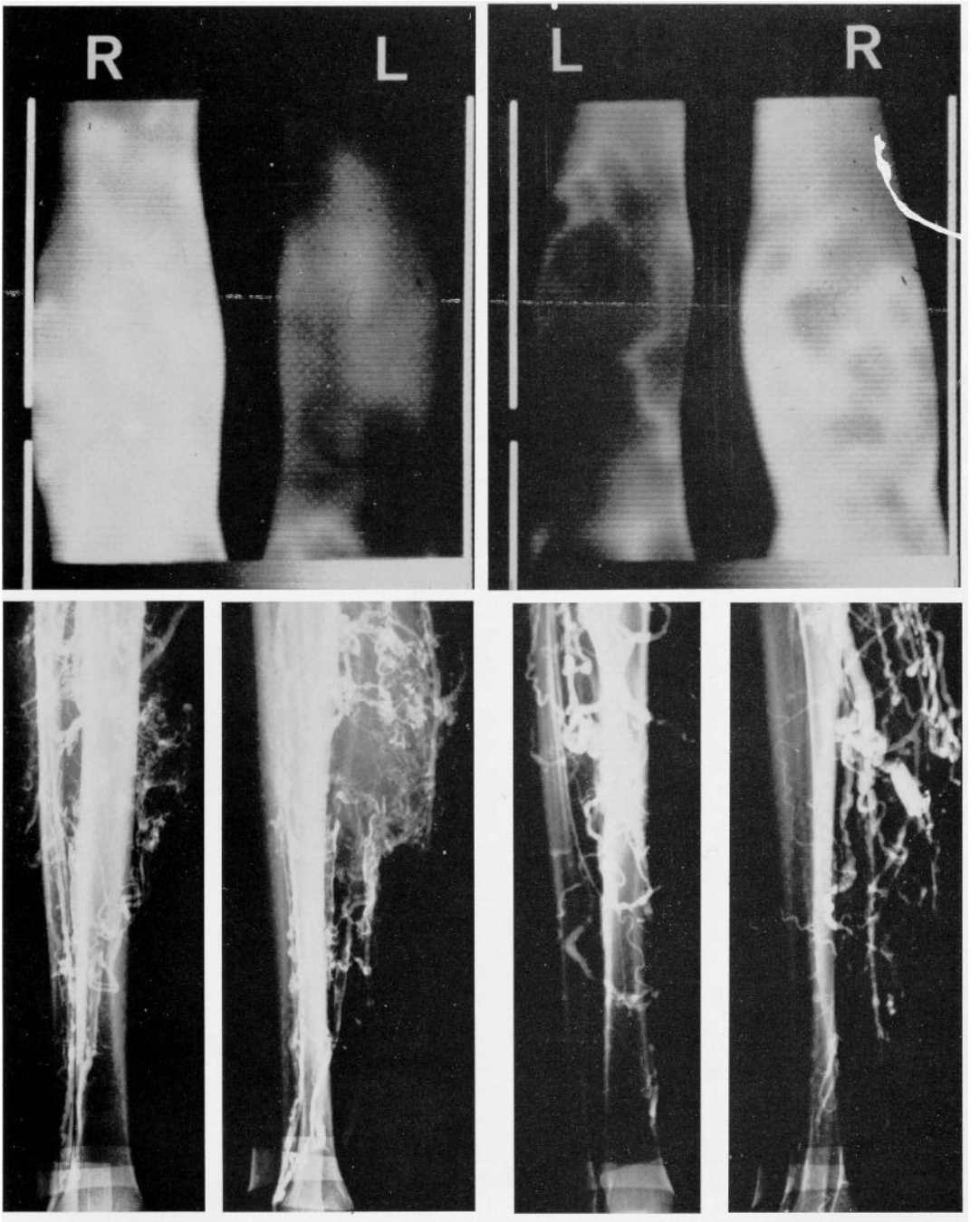
Case E. *Monitoring patients with thermographic scanning following surgery. Serial thermograms of 67 year old male patient after hip surgery.* Day 1 (upper). Some loss of tibia1 coolness in the left calf. Day 2 (bottom right). The changes are more marked with an obvious general increase in calf temperature. Day 3 (bottom left). Gross changes associated with a whole leg-vein thrombosis.



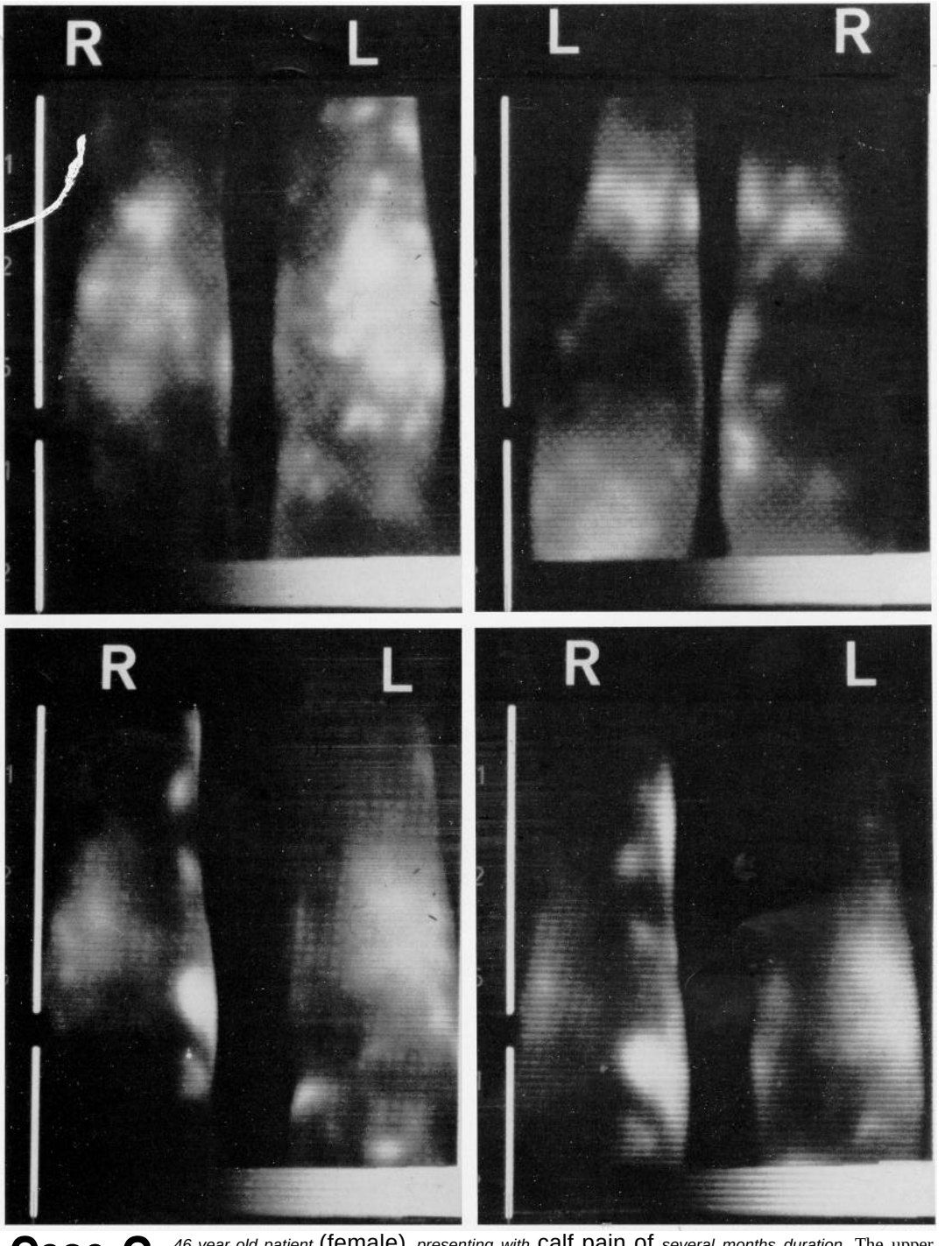


Case E cant'd.

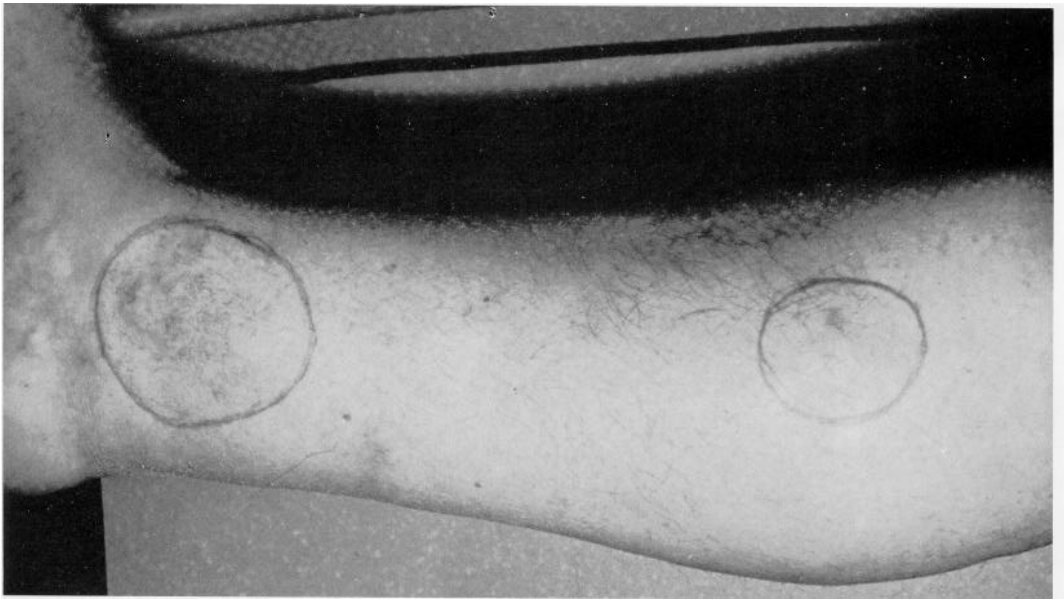
Day 3. The phlcbogram shows a recent whole-leg vein thrombus of the left leg. The normal (right) leg is shown for comparison.



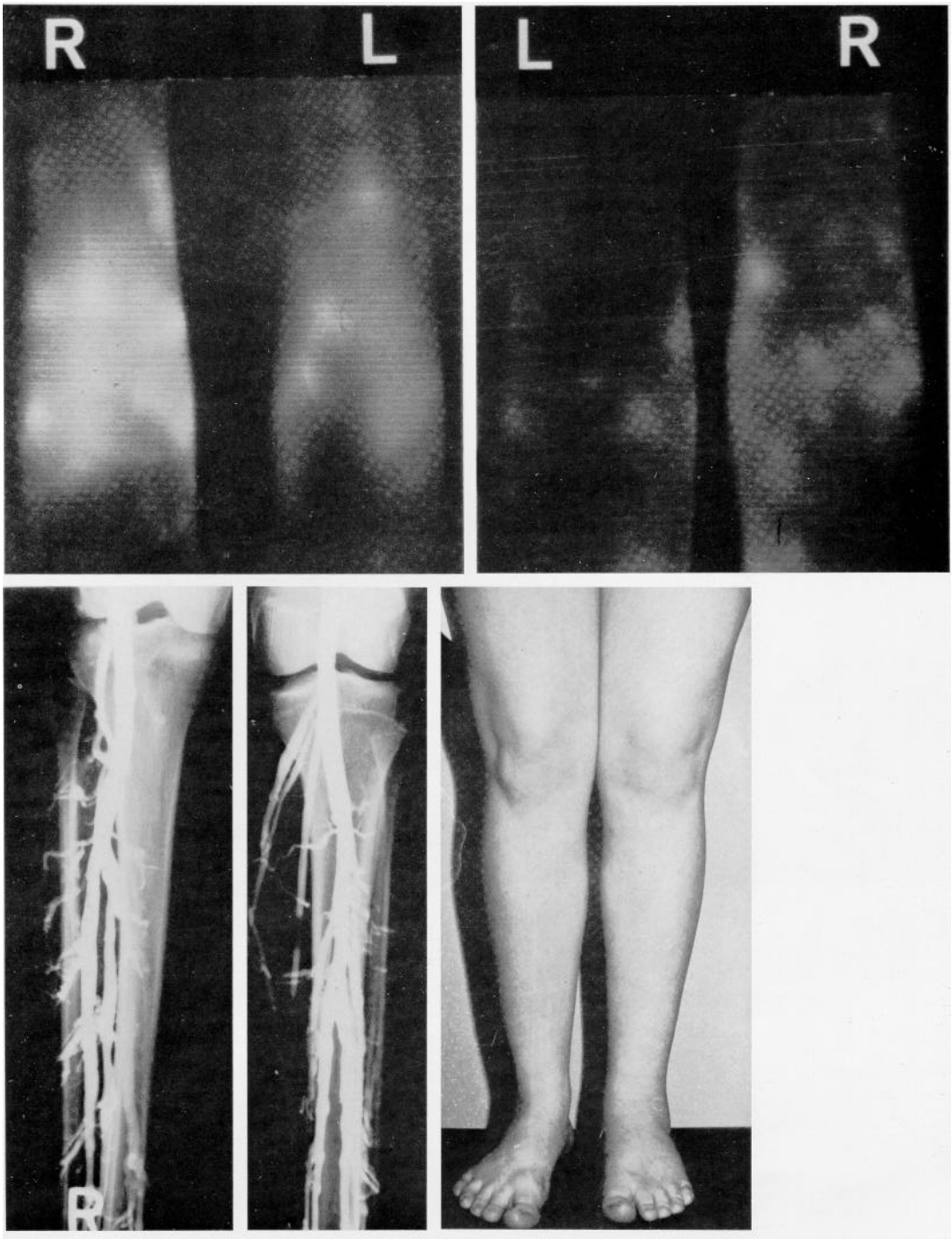
Case F. *60 year old male presenting with right calf pain* of *4 days duratron.* Sudden onset and no history of precipitating incident. Tender, slightly oedematous right calf. Left leg normal. Supine thermogram (upper left) shows a diffuse increase in temperature of the whole right calf. The<<blotchy>> or uneven distribution suggests a recent DVT complicating chronic venous insuffkiency. The pattern of the left calf is normal but discrete linear hot-spots suggest venous insufficiency of this leg also. Prone thermogram (upper right): the features seen on the supme thermogram are more evident on the prone view. The phlebograph of the right calf shows gross distortion of venous anatomy and fresh thrombi. The left calf shows a similar pattern of venous insufficiency but there are no recent thrombi.



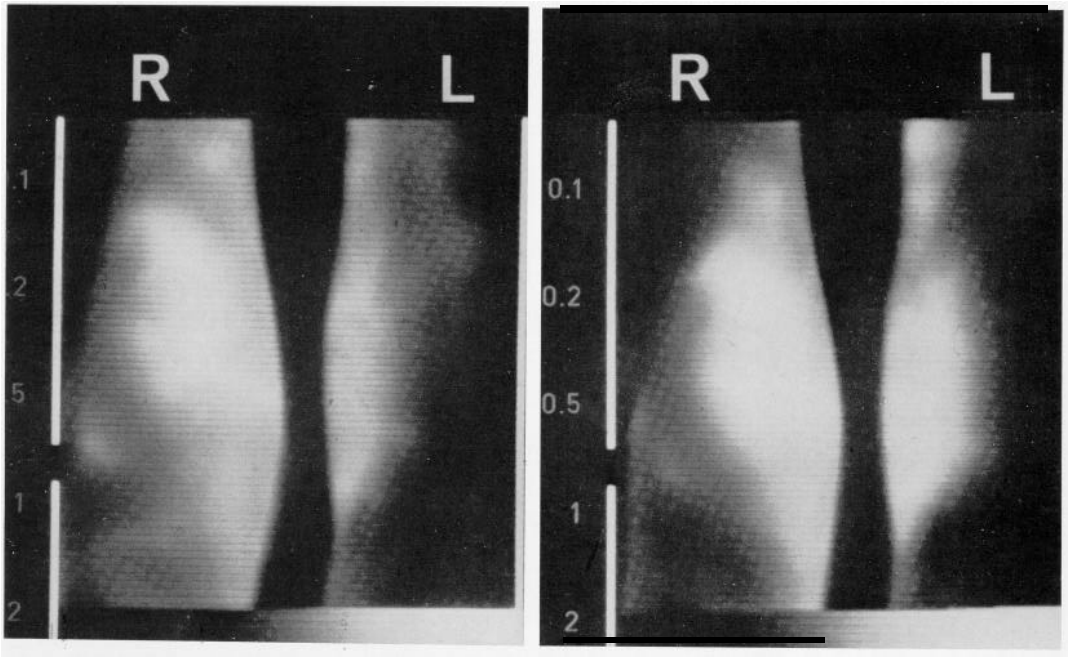
Case G *46 year old patient* (female) *presenting with* calf pain of *several months duration.* The upper resting supine and prone thermograms demonstrate the typical appearances of chronic venous insufficiency. In the bottom ((after-exercise)) thermograms incompetent perforators are evident.



Case G cant' d. The photograph of the legs indicates the sites of incompetence as shown by ultrasound.



Case H *19 year old patient complaining of swelling of the left ankle and foot for 3 days after commencing oestrogen therapy.* Supine thermogram (upper left) demonstrates an increased temperature of the right calf with normality of the left calf. The prone view (upper right) of the limbs rules out the possibility of DVT. The normal phlebogram is shown for comparison. The photograph of the legs demonstrates swelling due to oedema. The most likely cause of the increase in the temperature of the right anterior calf was an anterior tibilial tenosynovitis.



Case I. *77 year old male patient after right total hip arthroplasty.* The thermogram on the left (third post-operative day) shows the appearance typical of a calf vein thrombosis on the right side. The increase in the temperature of the left calfmedially suggests thrombosis of the soleal veins. The thermogram on the right (fifth post-operative day) shows a similar pattern in the right calf as that found on the third post-operative day. However, the area of increased temperature of the left calf is more extensive than previously.

Case I cant' d. Photograph of legs taken on the fifth postoperative day immedrately poor to phlebography. This photograph is of special interest as it demonstrates a common finding. A symptomatic, swollen right leg and an asymptomatic, apparently normal left leg. However, deep venous thrombosis is present in both calves as shown by thermography and contrast phlebography. The phlebograph shows the filling defects typical of recent deep venous thrombosis in both calves.

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