Venous Stasis in the Lower Extremities *

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LOCAL INJURY, abnormal blood coagulability and venous stasis have all been suggested as factors initiating thrombosis in human leg veins. As early as 1846, Virchow [8] advanced the belief that pulmonary emboli arose from thrombi in the femoral and pelvic veins, and that the thrombi formed in eddies on the central side of the larger valves.

Our own studies [5] showed a marked tendency for thrombi to begin at the apices of valve pockets. Venous stagnation was suggested as the cause of minor changes in the lining endothelial cells which led to the primary thrombus deposition. The usual site of thrombus attachment was at, or near, the apex of the pocket—at the point where stasis of blood should be most extreme. Microscopically the thrombi showed the greatest degree of organization at the apex, and a more recent structure as they extended up the pocket before emerging from its mouth. Complete serial section of 21 incipient thrombi showed that local injury or disease of the vein wall, as studied by ordinary staining technics, was not a factor in the precipitation of these bland venous thrombi in the lower extremities. Special staining technics, as devised by O'Neil,[4] Samuels and Webster,[7] and Robertson, Moore and Mersereau,[6] have shown minute endothelial changes with minor injuries, but were not applicable to the postmortem human material on which our observations were based.

Studies of stasis in postphlebitic venograms have been complicated by the abnormal communications between the superficial and deep veins. The pattern of the deep venous circulation was often obscured. We have now studied venous stasis in the legs of patients who required intravenous pyelography. We used only those free from known disease of the peripheral arteries or veins or from any pelvic or abdominal obstruction to venous flow. Twenty-five cc. of 50 per cent diatrizoate (Hypaque), after a 2-cc. initial dose, was injected in 15 seconds into a dorsal vein of the foot and directed into the deep veins by a tourniquet at the ankle. Cine radiographic and rapid casette changer technics allowed us to study venous flow and venous stasis in these normal systems. About 100 subjects have now been examined.

Stasis in valve pockets has been seen repeatedly, and is shown in Figures 3, 4 and 5.

This seemed strong support to our belief that thrombosis beginning behind valve pockets, as shown in Figures 1 and 2, was on the basis of venous stasis. It strengthened our belief that venous stasis was a prime factor in initiating thrombosis in the human leg, and thus often basically responsible for the sequence ending in pulmonary embolism.

Similar retention of dye was noted in the venous saccules of the calf muscles. Cine radiographic studies showed that contractions of the calf muscles forced this retained blood into the main channels in stream-lines, as described in the abdominal vena cava by Franklin and McLachlin.[1]

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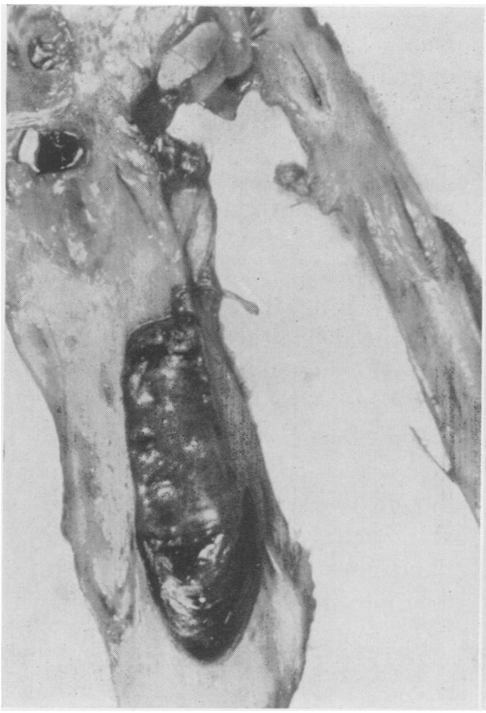


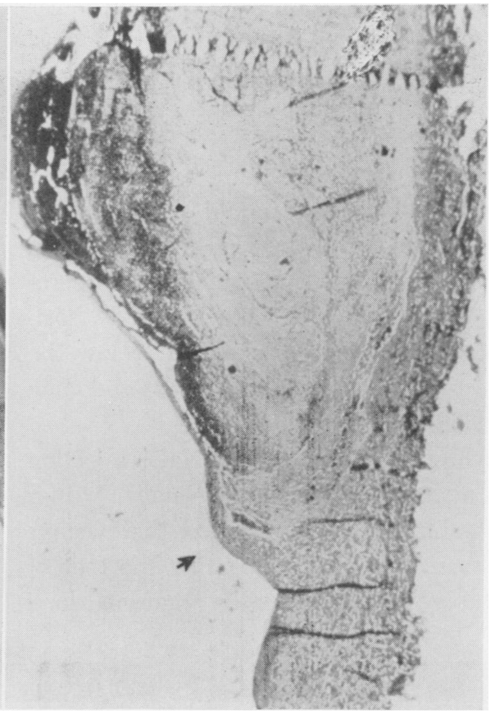


FIG. 1. (left) Large thrombus, arising from a single valve pocket in the superficial femoral vein and showing grossly visible lines of Zahn. It had resulted in a fatal pulmonary embolus.
FIG. 2. (right) Low power photomicrograph of part of a complete serial section through an incipient venous thrombus. The direction of blood flow is from below upwards. The thrombus completely fills a valve pocket. At its apex (arrow) it shows extensive organization, while proximally it is progressively younger. Heidenhain from × 10.

Twenty-five patients who could simulate operating room conditions by remaining quiet in the supine horizontal position showed unexpectedly long clearance time of the venous channels and of the valves or other pockets in the lower extremities. A number of methods that seemed capable of lessening stasis were then tested against this base line (Table 1).

Delay in emptying was longer in older patients. Gibbs [3] described a progressive distortion and dilatation in the veins in the soleus muscle with advancing age. This, along with general reduction in body activity, could be responsible for this increased delay. The series were carried out in sequence, and there is considerable variation in the average age in the groups. The retention of dye in leg pockets, as related to age in each series, is shown in the succeeding figures.

Discussion

Dye retention in the horizontal supine position with the lower extremities quiet seemed long, but was confirmed in 25 subjects. There were several elderly patients in this group, and stasis tended to be longer with advancing age. This effect of age was present in all series, but was most evident at rest in the horizontal position.

The striking reduction in stasis was with 15 degrees elevation of the foot of the table as shown in Figure 9. It was more effective than vigorous contractions of the thigh and calf muscles in the horizontal position. The 12 patients in each of these groups were close to the same average age and seemed suitable for comparison. The clearance time with the body horizontal and 15 degrees elevation at the hips was longer, but was in an older age group. It was still considerably shorter than with the body and lower extremities horizontal. If thrombosis begins, as we suspect, in the period of inactivity during and immediately following operation, this reduction in stasis with elevation of the foot of the operating room table, or recovery room bed, should prove worthwhile. We selected the 15-degree elevation as the maximum tilt at which most operations could be done. With the body horizontal and 15 degrees elevation below the hips procedures in the upper abdomen could be carried out.

Payling Wright,[9] using $^{24}NaCl$ injection into a foot vein and a Geiger Muller counter at the groin, showed that venous flow was doubled by elevating the foot of the table 10 degrees or by vigorous dorsi and plantar flexion of the foot. Frimann-Dahl[2] measured by x-ray the time required for radio opaque material to reach the groin when injected at the ankle, and noted that elevating the foot of the bed 30 cm. speeded the rate of flow. Neither reported stagnation in pockets as we have shown with radio opaque dyes and serial x-ray studies.

Very little dye was ever seen in the superficial veins of these patients with normal valves who had had dye forced into the deep veins below the ankle. The addition of compression bandages to 15 degrees elevation did not lessen venous stasis, though the series were not quite comparable because of difference in average age. Bandaging has been thought to divert all flow into the deep veins.

FIG. 3. (left) Venogram of the thigh made one minute after injecting 25 cc. of 50 per cent Hypaque into a dorsal vein of the foot with a tourniquet at the ankle. The superficial femoral vein is well outlined and the pockets behind the valves well filled. FIG. 4. (right) three minutes after the Hypaque injection shows in larger scale a partial clearance of the vein and indicates stasis in the valve pockets by the comparatively denser shadow of the pockets.

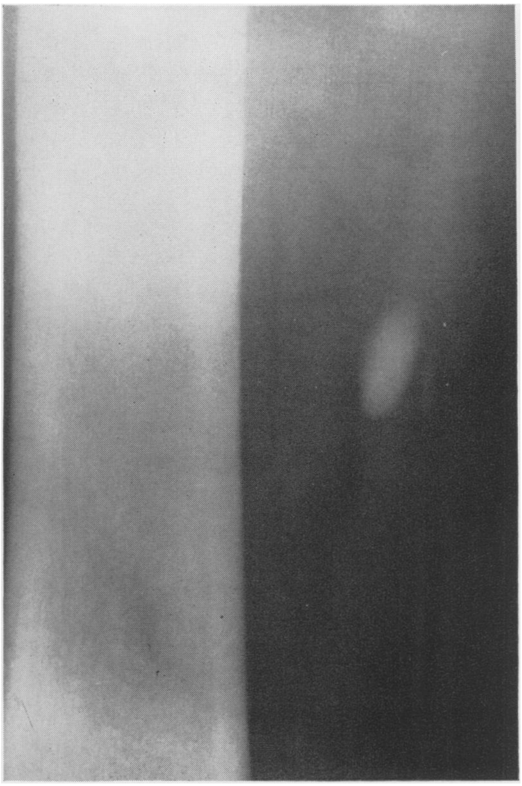


FIG. 5. Five minutes after the Hypaque injection the main channel of the vein is almost cleared. There is still good concentration in the backwater of the valve pockets. Further x-rays showed that the pockets were not empty until 12 minutes after the injection.

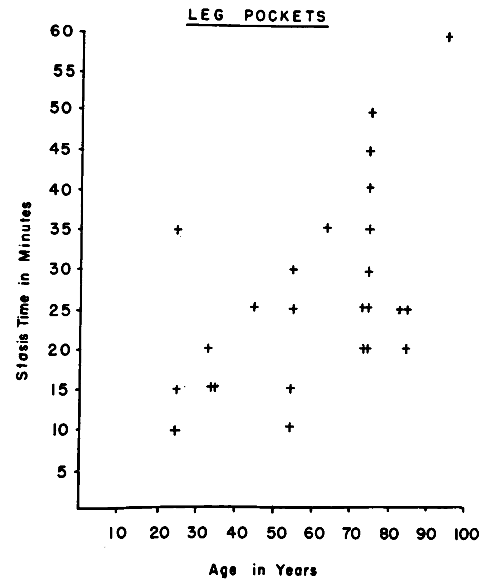
FIG. 6. A venogram of the leg made following Hypaque injection. On the left, one minute after injection, the deep veins and venous saccules are well outlined. On the right, ten minutes after injection, the venous channels are almost clear, but retention of the dye is still evident in the saccules. These local collections were visible for 25 minutes after the injection.

We produced effective contractions of the thigh and leg muscles in anaesthetized patients by percutaneous electrical stimulation.[4] These contractions were not as useful as voluntary muscle movements in speeding venous return. Elevation of the foot of the table was much simpler.

TABLE 1. *Stasis in Normal Human Lower Extremity Veins*

Method	No. of Cases	Average Age	Thigh Channels (min.)	Thigh Pockets (min.)	Leg Channels (min.)	Leg Pockets (min.)
Horizontal	25	62 years (20–93)	9.2	21.0	10.6	27.0
Horizontal active exercise	12	45 years (15–79)	3.4	8.3	3.9	9.3
15⁰ Elevation foot table	12	42 years (17–94)	2.1	5.4	1.9	4.8
Body horizontal 15° elevation at hips	12	50 years (20–81)	4.1	12.0	2.8	9.5
15° Elevation elastic bandages	12	63 years (17–85)	2.5	10.0	2.6	8.6

Shows the retention of dye in channels or in valves or other pockets under a variety of conditions as compared to the supine horizontal position. All end points were read from x-ray films by one member of the Department of Radiology.



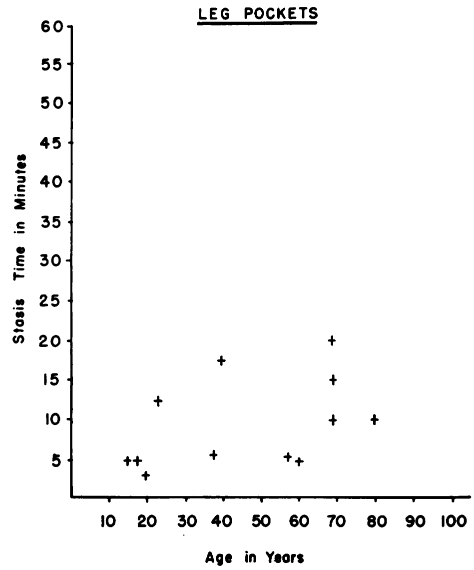
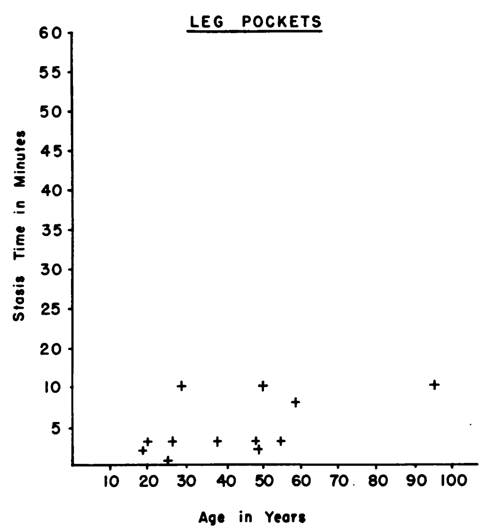


FIG. 7. (left) The relationship of age to retention of dye, in the legs of the 25 patients examined in the supine horizontal position. FIG. 8. (right) The vigorous contraction of the thigh and calf muscles in the horizontal position is shown.



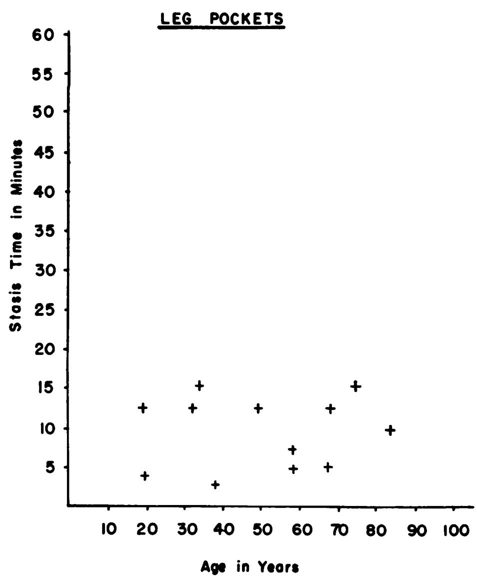


FIG. 9. (left) The effect of elevating the foot of the table 15 degrees. FIG. 10. (right) with the body horizontal and 15 degrees elevation at the hips.

Summary

1. Venous stasis has been studied in normal human lower extremities during intravenous pyelography. Cine radiographic and rapid casette changer technics were used.

2. Stasis in valve pockets and venous saccules was very evident, and supported our views that it was in large part responsible for the origin of thrombi in these areas. Stasis time was longer with advancing age.

3. Fifteen degrees elevation of the foot of the table markedly reduced this stasis and was more effective than vigorous voluntary contractions of the thigh and calf muscles with the body and lower extremities horizontal. This suggested that 15 degrees elevation of the foot of the operating room table and recovery room bed was the simplest and perhaps most effective single measure against that lethal sequence of stasis, thrombosis and embolism beginning with an operative procedure.

Acknowledgment

We wish to thank the Department of Radiology, Victoria Hospital, London, and in particular Dr. John R. Rhodes, for help with this work.

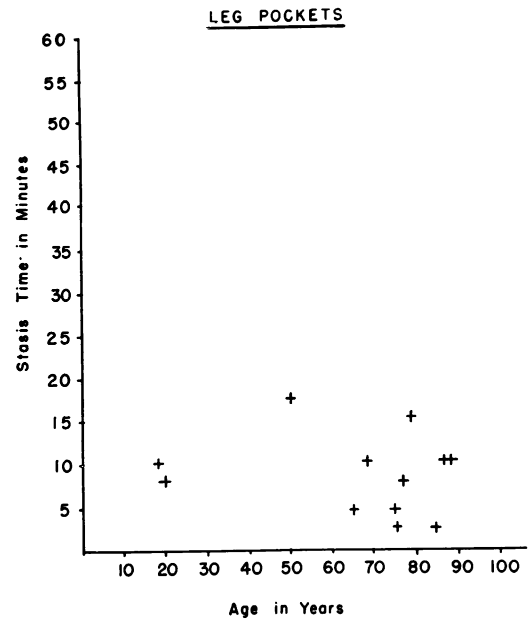


FIG. 11. Shows the effect of 15 degrees elevation of the foot of the table plus elastic bandages.

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DISCUSSION

DR. ROCKE ROBERTSON: I have had an opportunity of following this work of Dr. McLachlin's for some time. It has struck me as being a most ingenious way of demonstrating the factor of stasis which everybody agrees is important in the induction of thrombosis but which I think everybody has found very difficult to demonstrate in the clinical case and even to test experimentally. This, I think, is a nice method of demonstrating