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Phleborheography: A Correlative Study with Venography†

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The Vascular Laboratory of Henry Ford Hospital has used the Cranley-Grass Phleborheograph (PRG) as the primary noninvasive method to determine the presence or absence of deep venous thrombosis (DVT) in the lower limbs since December 1977. In order to determine its proper role and clinical reliability, we compared the diagnostic accuracy of phleborheography with contrast venography. From December 1977 through December 1978, 483 cases (963 limbs) were successfully examined by PRG. Of these, 111 cases (216 limbs) also had contrast venography. The PRG was confirmed as normal in 151 out of 157 (6 false negatives). There were 53 abnormal PRGs, with 35 confirmed by venography and 18 false positives. Six PRGs were considered equivocal. Sensitivity on a per limb basis was .85. The overall specificity was .86, and when equivocal examinations were excluded, it was .89.

Phleborheography is safe, reliable, widely applicable, and well-tolerated. However, skilled technicians and careful interpretation are essential to its success.

During the past two years, we have used the Cranley-Grass Phleborheograph (PRG) as the primary noninvasive method to determine the presence or absence of deep venous thrombosis (DVT) in the lower limbs. Others have reported the PRG to be a reliable clinical tool (7). Although venography is still considered the standard for diagnostic accuracy, its routine use entails some discomfort and risk (2). In order to determine the proper role and clinical reliability of the PRG in our blood flow laboratory, we undertook a correlative study comparing the diagnostic accuracy of phleborheography with contrast venography in 111 cases (216 limbs).

Clinical Material

Our study group consisted of 426 patients who were seen by the Division of Vascular Surgery between December 1977 and December 1978 to establish the diagnosis of deep venous thrombosis. Bilateral phleborheographs were attempted 498 times. Although a successful examination was completed in 483 cases (963 limbs), the test was technically unsatisfactory in 15. In seven cases, the PRG was complicated by uncontrolled body movements caused by associated diseases. In eight cases, orthopaedic restrictions made it impossible to adjust body position adequately.

Bilateral lower limb venography was also successfully performed on 111 (216 limbs) of the 483 successful PRG cases. The clinical presentation of these 111 cases included: leg swelling and/or pain (93); chest pain suggesting pulmonary embolus (6); both lower limb and chest symptoms (5); and superficial phlebitis (2). Five asymptomatic cases underwent baseline studies.

Methods

The phleborheograph is a method of plethysmography which traces the flowing currents within the deep venous system (5). Physiologically, it consists of a set of low pressure plethysmographic recordings of repetitive lower limb expansions, which are referred to as "respiratory waves". The waves reflect intermittent slowing of the deep venous flow in the lower limbs due to the rhythmic diaphragmatic compression of the intra-abdominal vena cava with each inspiration (Fig. 1). This is the same pressure that augments flow of blood toward the heart during inspiration, the femoral veins, and sometimes the iliacs being supplied with valves (3).

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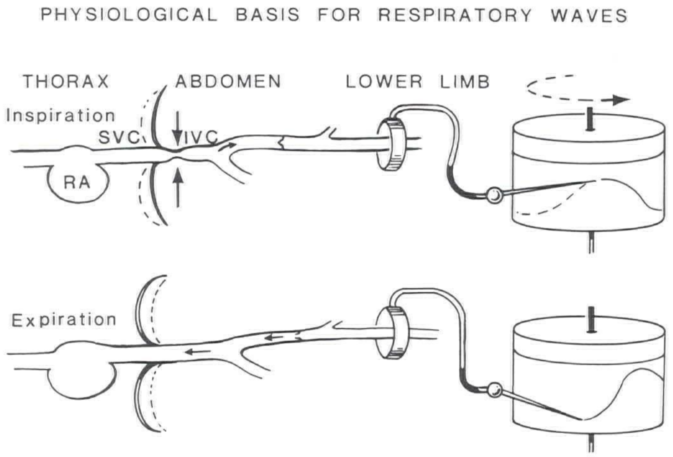

Fig. 1
Artist's conception of effect of diaphragmatic motion on respiratory waves. In the upper diagram depression of the diaphragm during inspiration causes an increase in the intra-abdominal pressure. This pressure then slows venous return from the lower extremities so that a plethysmographic increase in size of the limb occurs. The lower diagram shows the reverse effect during expiration. Adapted in part from Balzer, et al (1).

Each PRG was performed with a standard Cranley-Grass Phleborheograph (Model PRG) used as recommended by Cranley, et al (4,5). The patients were placed in a comfortable position with their feet lower than their heart on a standard hospital bed in the Clinical Vascular Laboratory. Each PRG was interpreted by the technician as it was being performed so that adjustments could be made in the patient's position in order to obtain a reliable examination. The completed study was interpreted by a physician as either normal, abnormal, or equivocal.

The three criteria used to interpret the PRG results in order of significance were: 1) change or loss of "respiratory waves"; 2) elevations in the baseline of the graphs when standardized compressions were applied to the foot (Run A) or the calf (Run B); and 3) evidence of "foot emptying" during compression of the lower calf cuff. This third criterion was helpful when present, but because of technical variations, its absence could not be relied upon for diagnostic validity.

The contrast venograms were performed with the patient placed in a supine, horizontal position using tourniquets to encourage filling of the deep veins. Both a radiologist and a surgeon read each venogram. In the rare instances that the readings did not agree, the abnormal interpretation was used in the study.

Results

The results of correlating the phleborheograph with the venogram in 216 limbs are given in Table I. There were 157 normal PRG results. Of these, 151 were confirmed by venography, but six proved to be false negative interpretations. Of the 53 abnormal PRG tests, 35 were confirmed by venography, but 18 were found to be false positives.

TABLE I

Correlation of Results of Phleborheograms with Venography in 216 Limbs

Venogram Result	Phleborheogram Results: Normal	Abnormal	Equivocal	Total
Deep Venous Thrombosis	6	35	0	41
Normal	151	18	6	175
Total	157	53	6	216

Note: Sensitivity = $\frac{\text{Number of Abnormal PRGs with DVT}}{\text{Total Limbs with DVT by Venogram}} = \frac{35}{41} = .85$

Specificity = $\frac{\text{Number Normal PRGs without DVT}}{\text{Total Limbs with Normal Venograms}} = \frac{151}{175} = .86$

Specificity Excluding Equivocal PRG Results $= \frac{151}{169} = .89$

The sensitivity on a per limb basis was .85. The overall specificity was .86, but if the six equivocal examinations are exluded, the specificity was .89. In other words, the PRG gave a positive result in 85% of all patients who actually presented with deep venous thrombosis of any degree or location, as determined by venography. It gave a normal result in 86% of the patients who presented with the possibility of deep venous thrombosis and subsequently had a normal venogram.

The six false negative tests (Fig. 2) involved thrombi in the popliteal (3) or infrapopliteal veins (3). The anatomical locations of the 35 thrombi detected by PRG are listed in Table II. The cephalad extent of the thrombotic process involved 19 iliac veins (54.3%); 6 femoral veins (17.1%); 5 popliteal (14.3%); and 5 thrombi of more than one named infrapopliteal vein (14.3%). All thrombi in the iliac and femoral veins were detected. In addition, 63% of DVT involving the popliteal veins were also detected. When the thrombi were limited to the infrapopliteal region, multiple vein involvement was detected five times (100%), but single vein occlusion, which occurred three times, was not detected.

Discussion

The PRG has a number of advantages. It is comfortable, safe, economical, easily repeated, and reliable. For these reasons, it is readily acceptable to both patients and physicians. Also, the equipment is very durable. In our labora-

TABLE II

Anatomical Location of 35 Thrombi Detected by PRG

Level of Deep Venous Involvement	N	Limbs	(%)
Iliac + two or more distal levels	14	19	(54.3)
Iliac + Femoral	4		
Iliac	1		
Femoral + Popliteal + Infrapopliteal	2	6	(17.1)
Femoral + Popliteal	2		
Femoral	2		
Popliteal + Infrapopliteal	4	5	(14.3)
Popliteal	1		
Three Named Infrapopliteal	3	5	(14.3)
Two Named Infrapopliteal	2		
One Named Infrapopliteal	0		(0)
Total	35		(100)

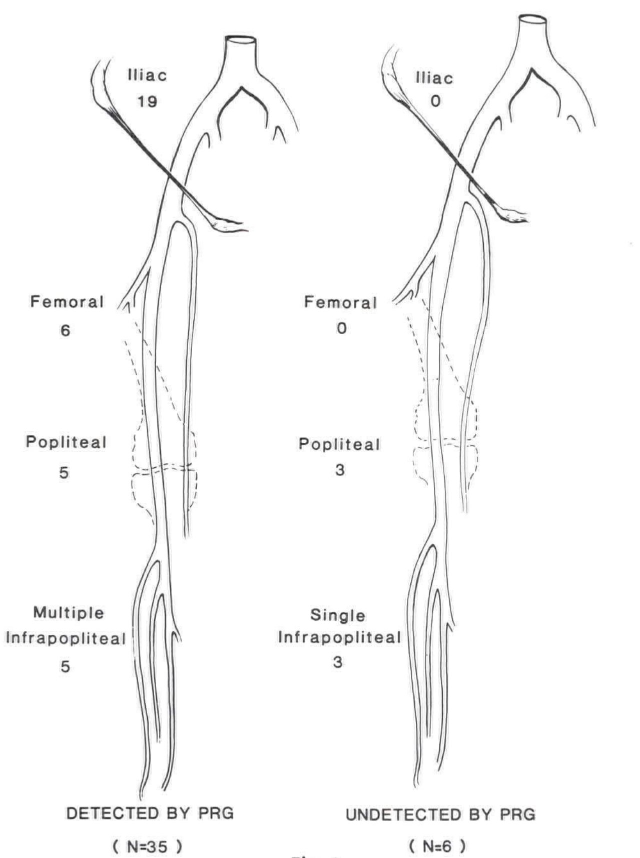

Fig. 2

The anatomical location of the cephalad extent of 41 thrombi detected by venography in the evaluation of 216 limbs. The firgure on the left depicts the levels of 35 thrombi also detected by PRG. The firgure on the right illustrates the six thrombi which were not detected by PRG.

tory, during the past two years, the Cranley-Grass PRG has been out of service only once for a short period.

There are, however, some disadvantages in using the PRG. From an anatomical standpoint, thrombi in the major tributary veins, such as the hypogastric, deep femoral, and subcutaneous (greater and lesser saphenous) veins do not cause changes that can be detected by PRG (6). If the PRG is delayed long enough for rich collateralization to develop following an acute thrombosis, the obstructive pattern in the test may be attenuated or absent.

Another consideration is the personality and empathy of the technicians performing the test. This factor is critical because patient cooperation is necessary to achieve accurate results. Also, the technician must have the persistence to place the patient in various positions, as well as full knowledge of the various patterns of abnormal PRGs, in order to perform a valid test. This is especially important if an undue number of false positive examinations is to be avoided.

There are still other limitations. Because of its size, the PRG is not easily portable. Also, we have found that patients confined to their rooms generally do not cooperate fully either because of their primary disease or environmental distractions. Associated medical problems may limit the patient's ability to move freely and relax to a reasonable extent. Medical diseases or anxiety causing tremulous motion or excessive tension will interfere with completion of the examination. Moreover, it is difficult, or impossible, to perform an accurate test if the patient is immobilized by casts or orthopaedic traction devices, or is using a respirator.

Interpretation of a phleborheograph, which is displayed in an analogue or graph form, remains a subjective art and requires experience to maintain a high degree of accuracy. This correlative study between phleborheography and venography carried out in our laboratory during its developmental period showed that we had not attained the accuracy of Cranley, et al (7). Our study had six equivocal tests (2.7%) compared to 1.5% equivocal results in the Cranley series. While our sensitivity was 85% and overall specificity was 86%, the larger, previously reported series contained only 5.2 - 8% false negatives and only 1.9 - 4.5% false positive results.

Clinical data of the six false negative examinations were critically reviewed. In three cases thrombi were limited to a single infrapopliteal vein which prevented physiologic obstruction or detectable changes in the PRG. An additional case with popliteal vein obstruction was examined two weeks after symptoms began. The phleborheogram was normal, and venography demonstrated the presence of excellent collateral veins. The two-week delay between the onset of symptoms and PRG examination allowed collaterals to develop and virtually eliminated physiologic obstruction, thereby making detection by PRG extremely difficult. Another case, with thrombosis in the popliteal and infrapopliteal veins, has associated disease which limited the effectiveness of the PRG. This patient weighed over 300 pounds, had previously been treated with a cardiac pacemaker, and was experiencing episodes of Pickwickian respiratory distress. Also, because she could not speak English well, she could not follow the technician's instructions clearly. In retrospect, we believe that this patient's phleborheograph should not have been considered completely satisfactory. The sixth patient had involvement of infrapopliteal veins and thrombus extending into the proximal popliteal vein. This false negative was due to an error in interpretation of the PRG, and, after review, it was clearly abnormal.

The reasons for the 18 false positive examinations were more difficult to ascertain. However, the retrospective analysis revealed a wide variety of complicating factors: uncooperative patients (4); anatomic factors such as possible distortion of femoral or iliac veins due to wound edema or hematoma, or the mechanical limitations imposed on testing equipment by obesity (4); interpretative errors (3); technically imperfect tests (2); possible postphlebographic phlebitic change in patients who had venograms prior to phleborheography (2). Three cases had no discernible, extenuating circumstances that would have affected the interpretation.

Further, relative to the incidence of false positive tests, it should be mentioned that all errors in technique tend to cause a false positive examination. The technician strives to eliminate the positive findings and any lack of cooperation by the patient that cannot be overcome tends to cause a false positive test. In addition, during a portion of the test year, because of several false negative tests involving the infrapopliteal area, the physicians interpreting the examinations began to overread results and place too much emphasis on the quality of foot emptying.

In one of two cases evaluated for superficial phlebitis, a major unsuspected deep popliteal thrombosis was detected and confirmed. For these reasons, we now feel that every patient with superficial thrombophlebitis should have a phleborheographic or other noninvasive test for deep venous thombosis.

Summary

In our Clinical Vascular Laboratory, the phleborheograph has proven to be a practical and reliable noninvasive method of detecting deep venous thrombosis. After our findings were correlated with venography in 216 limbs, the sensitivity was determined to be .85 and the specificity .89. The test is well accepted by both the patients and the medical staff, and it has greatly added to our diagnostic accuracy without increased risk to the patient. However, like all laboratory tests, it must be interpreted for each individual patient in the light of existing circumstances. The primary difficulties encountered with the phleborheograph have been that it is technician-sensitive and, because of the analogue format, it requires experience in interpretation.

Currently, in our practice, if the PRG is normal, but unexplained symptoms persist that suggest deep venous thrombosis, the PRG is repeated at least once before a venogram is recommended. If the result of the phleborheograph is equivocal, then a venogram is recommended, provided there are no clinical contraindications.

References

1. Balzer K, Bernert J, Carstensen G. Die Beurteilung der Venösen Hämodynamik als entscheidendes diagnostisches Kriterium fur venenchirurgischce Eingriffe. Chirurg 1978;49:290-95.

2. Bernstein EF, Barnes RW, Dilley RB, et al. Role of noninvasive tests in the management of acute venous disease. In: Bernstein EF, Barnes RW, Dilley RB, et al, eds. Non-invasive diagnostic techniques in vascular disease. St. Louis: CV Mosby Co, 1978:404-08.

3. Best CH, Taylor NB. The physiological basis of medical practice. Baltimore: Williams & Wilkins, 1950:168.

4. Cranley JJ. Phleborheograph. In: Vascular surgery, Vol. II. Peripheral venous diseases. Hagerstown MD: Harper and Row, 1975;2:75-95.

5. Cranley JJ, Canos AJ, Sull WJ, Grass AM. Phleborheographic technique for diagnosing deep venous thrombosis of the lower extremities. Surg Gynecol Obstet 1975;141:331-39.

6. Cranley JJ, Canos AJ, Grass AM. Deep venous thrombosis of the lower extremity: Diagnosis by the Cranley-Grass Phleborheograph (Model PRG). From the Kachelmacher Memorial Research Laboratory, Good Samaritan Hospital, Cincinnati OH and the Grass Instrument Co. Quincy MA 1975.

7. Cranley JJ, Mahalingam K, Ferris EB. Diagnosis of deep venous thrombosis of the lower extremity by phleborheography. In: Bernstein EF, Barnes RW, Dilley RB, eds. Noninvasive diagnostic techniques in vascular disease. St. Louis: Leopold Co, 1978;351-58.