

## THE POTENTIAL USEFULNESS OF CONDENSED IMAGE PROCESSING OF SEQUENTIAL LYMPHOSCINTIGRAMS IN PATIENTS WITH LYMPHEDEMA

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### ABSTRACT

*Condensed image processing (CIP), a computerized technique of scintiscans that generates a vertical distribution of activity as a function of time in a single image, was applied to isotopic lymphoscintigrams of four patients with leg lymphedema. By "condensing" information gained from multiple images into a single image, CIP better evaluates ascending progression of radiolabeled colloid in peripheral lymph and better localizes stagnant areas. In "high lymph flow failure," CIP also depicts radioactive "bursts" suggestive of increased lymphatic truncal contractility. This data processing method improves interpretation of dynamic scintiscan recordings and seems ideally suited for evaluation of peripheral lymph kinetics.*

The potential value of isotopic lymphoscintigraphy to assess lymph dynamics has been recognized for more than 35 years (1). Recent improvements in radiopharmaceuticals and in imaging has led to renewed interest in lymphoscintigraphy especially in patients with lymphedema (2-6). Lymphatic vessels and nodes are sequentially visualized using a gamma camera connected to a computer. The "dynamic" lymphoscintigram has certain advantages over static images (e.g., it displays tracer kinetics in lymphatics including collateral pathways, and the

occurrence and origin of abnormal radioactivity in the soft tissues). Nonetheless, global visual inspection of all the images has proved difficult. Lymph dynamics are different in the interstitium and in the lymphatic vessels, and the usual ciné display consists of multiple images of small size and low tracer activity. On consecutive images the lymphatics tend to be narrow and often difficult to distinguish from tissue spaces. Accordingly, sequential images have to be laboriously examined one at a time. Transit times are usually followed by mean time-activity curves from regions of interest (7-10). Unfortunately, these interest areas are not standardized and therefore the shape of the curves tends to be arbitrary. In this study, we propose condensed image processing (CIP) of these recordings to circumvent these shortcomings. CIP successfully condenses into a single image temporal and spatial information from an entire dynamic image series. This data display method was first applied to esophageal transit (11-13), but it may also be applied to peripheral lymphoscintigrams where it depicts radioactivity changes in the direction of lymph flow (14).

### MATERIALS AND METHODS

#### *Lymphoscintigraphy*

In four adult patients, 3mCi of Tc-

99m ammonium sulfur colloid (111MBq) (lympho-vectoscint Solabco Laboratory) was injected subcutaneously into the first interdigital space of each foot. The subcutaneous tracer injection avoids the inadvertent puncture of cutaneous venules which occasionally occurs with intradermal injection. A wide field gamma camera (General Electric 520 T) connected to a data processing system (Sopha Simis V) was used for imaging. The sequential recordings consisted of 40 consecutive one minute images of ankles and legs immediately after tracer injection.

### *Recording Processing*

The computer method for depicting the dynamic sequence into a single image has been previously described (15). We performed condensed image processing, successively for each leg, after masking the contralateral leg. The sequential images of the dynamic series were originally in a 64x64 matrix. Each sequential image was compressed (by row summation) into a single one pixel vertical column which displayed the vertical distribution of radioactivity from the distal to the proximal portion of the leg within a one minute time interval. The condensed image was then reconstructed by putting these vertical columns side by side according to their frame number. Consequently, the condensed image displayed the ascending progression of radioactivity from the ankle to the knee along a vertical axis as a function of time on the horizontal axis. The condensed image of each leg thereby represented collected spatial and temporal data of the dynamic image series.

### *Clinical Results*

#### *Patient 1*

In a 37-year-old woman with moderate primary lymphedema of the left leg and foot, dynamic lymphoscintigraphic images (*Fig. 1A*) show the right side soon after injection with distal localized tracer activity followed by progressive tracer transport "upward" through a lymphatic

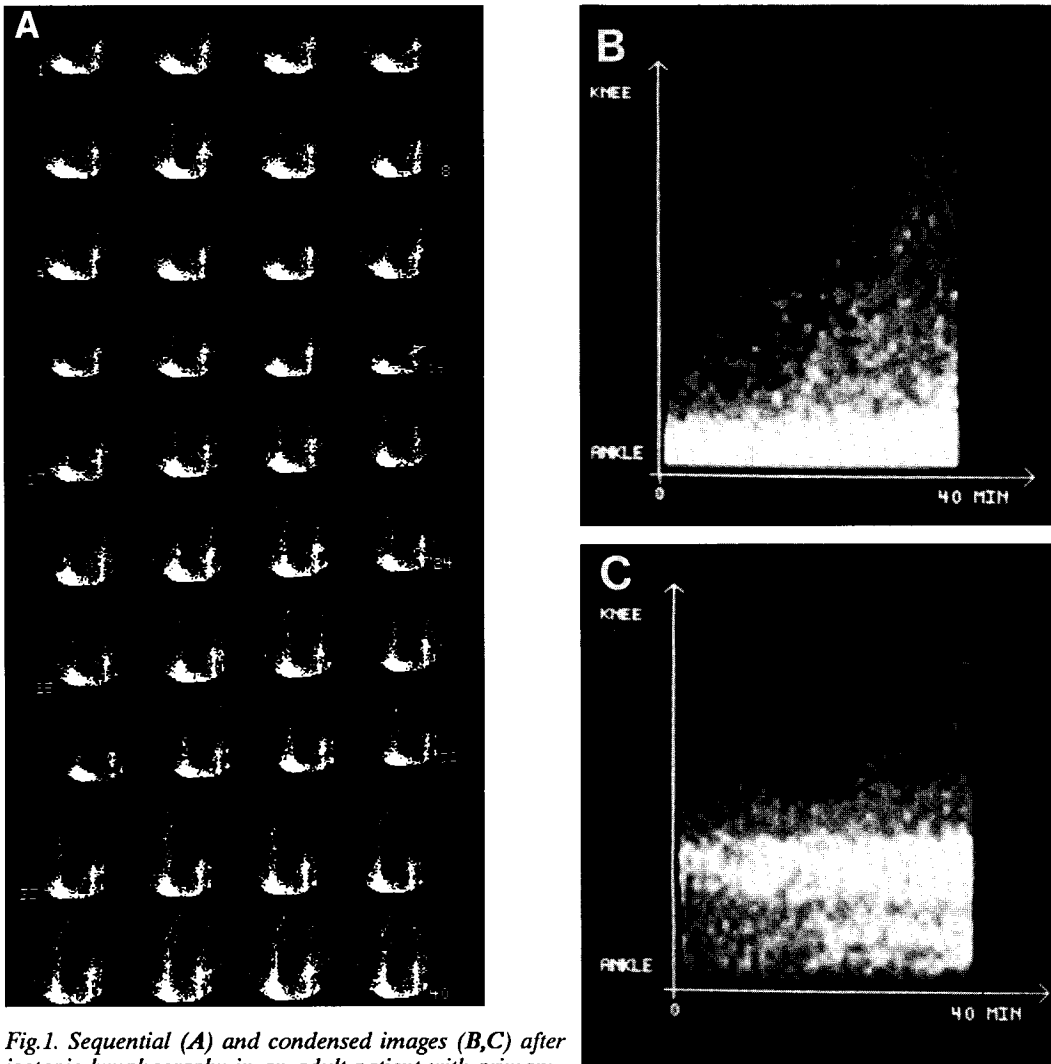
trunk. On the left side, tracer activity is localized in a lymphatic in the lower third of the leg with delayed lymph transport proximally. The condensed image of the right leg displays a normal pattern (*Fig. 1B*), with progressive and regular ascending radioactivity above a horizontal "band" that corresponds to local tracer diffusion at the injection site. On the other hand, the condensed image of the left leg (*Fig. 1C*) suggests lymphatic obstruction with collateral drainage pathways with an initial broad tracer activity front superior to a high radioactive horizontal band and then at 20 minutes (half-way) another tracer (lymph) influx and minimal radioactivity above the horizontal "band." The superior horizontal band corresponds to a stagnant area at the upper margin of the peripheral lymphedema.

#### *Patient 2*

A 44-year-old woman had bilateral leg lymphedema (mainly on the right) aggravated by chronic venous insufficiency. The sequential images (*Fig. 2A*) show on the right soon after the injection distal localized tracer activity with minimal ascending transport. In contrast, on the left, there is a rapid proximal migration of tracer through a dilated trunk. Condensed image on the right (*Fig. 2B*) displays intense radioactivity at the injection site and in the lower two-thirds of the leg but little or no ascending transport (lymphatic hypoplasia). The condensed image on the left (*Fig. 2C*) by comparison shows discontinuous tracer activity with an abrupt rise within two minutes after injection and multiple vertical tracer activity bands. The horizontal bands in the middle portion of the left leg are the most active (hyperdynamic lymphatic insufficiency).

#### *Patient 3*

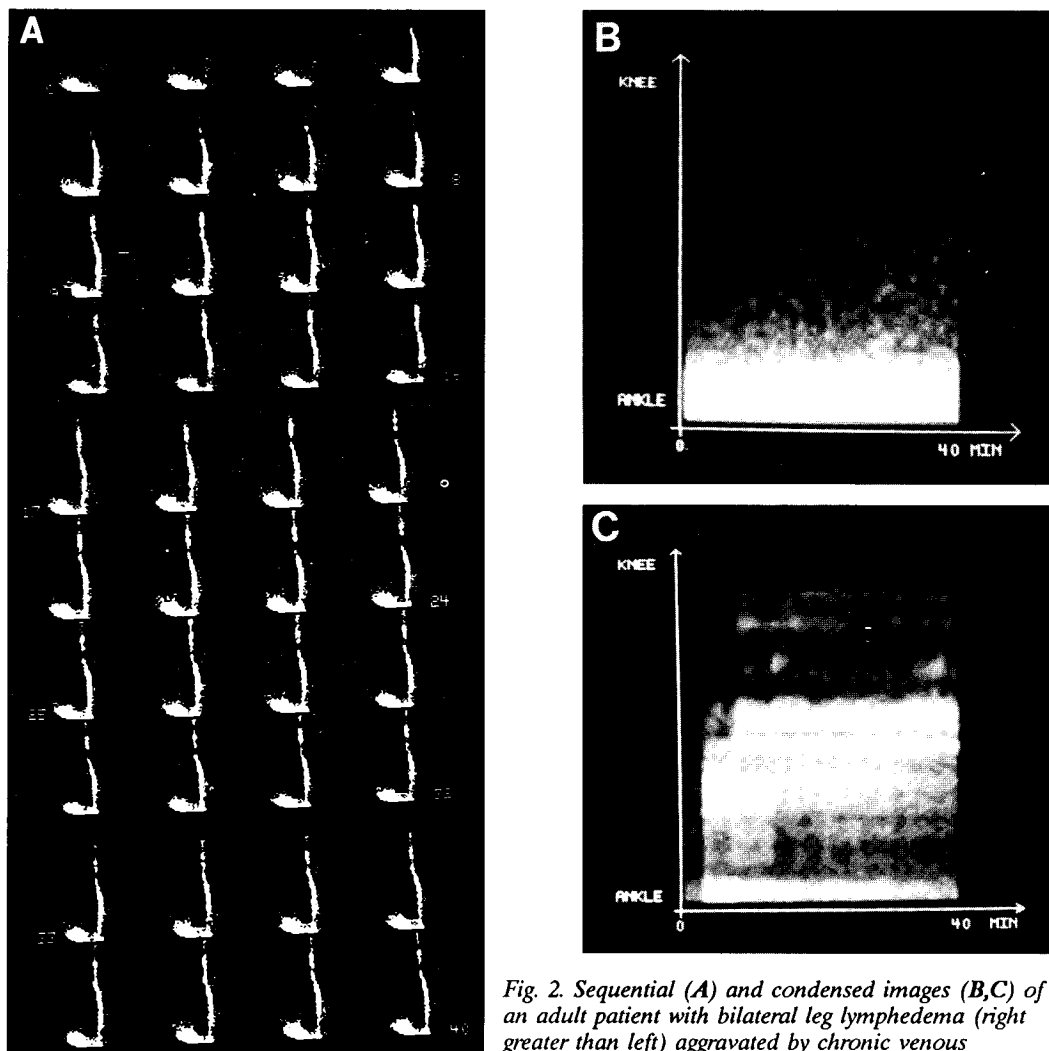
An 18-year-old woman had mild lymphedema of both legs. The deep venous system was unremarkable (Doppler ultrasonography). The sequential dynamic images (*Fig. 3A*) depicts on the right,



*Fig.1. Sequential (A) and condensed images (B,C) after isotopic lymphography in an adult patient with primary lymphedema of the left leg. Whereas the right leg shows early and progressive tracer transport proximally, on the left there is tracer "hold-up" in the lower third with delayed transport. These differences are accentuated on the condensed images where the right side (B) shows ascending radioactivity above a horizontal "band" that corresponds to tracer diffusion at the injection site. In contrast, the left leg (C) shows an initial broad tracer activity front superior to a radioactive horizontal band with minimal upward migration after 20 minutes. The latter pattern suggests stagnant transport with lymphatic obstruction.*

rapid transport of the radiolabeled colloid through an enlarged trunk and on the left early localized distal tracer activity with delayed lymphatic transport. The condensed image on the right (Fig. 3B) depicts an "enhanced pattern" with rapid tracer transport at five minutes after injection and prominent horizontal and vertical activity bands. The radioactivity of

the horizontal bands is higher in the lower leg (lymphatic hyperplasia). The condensed image on the left (Fig. 3C) displays a horizontal activity band in the lower third of the leg promptly after injection. At 25 minutes, there is a large radioactive influx from the injection site to the previous influx level with further progression of tracer to the knee (abnor-



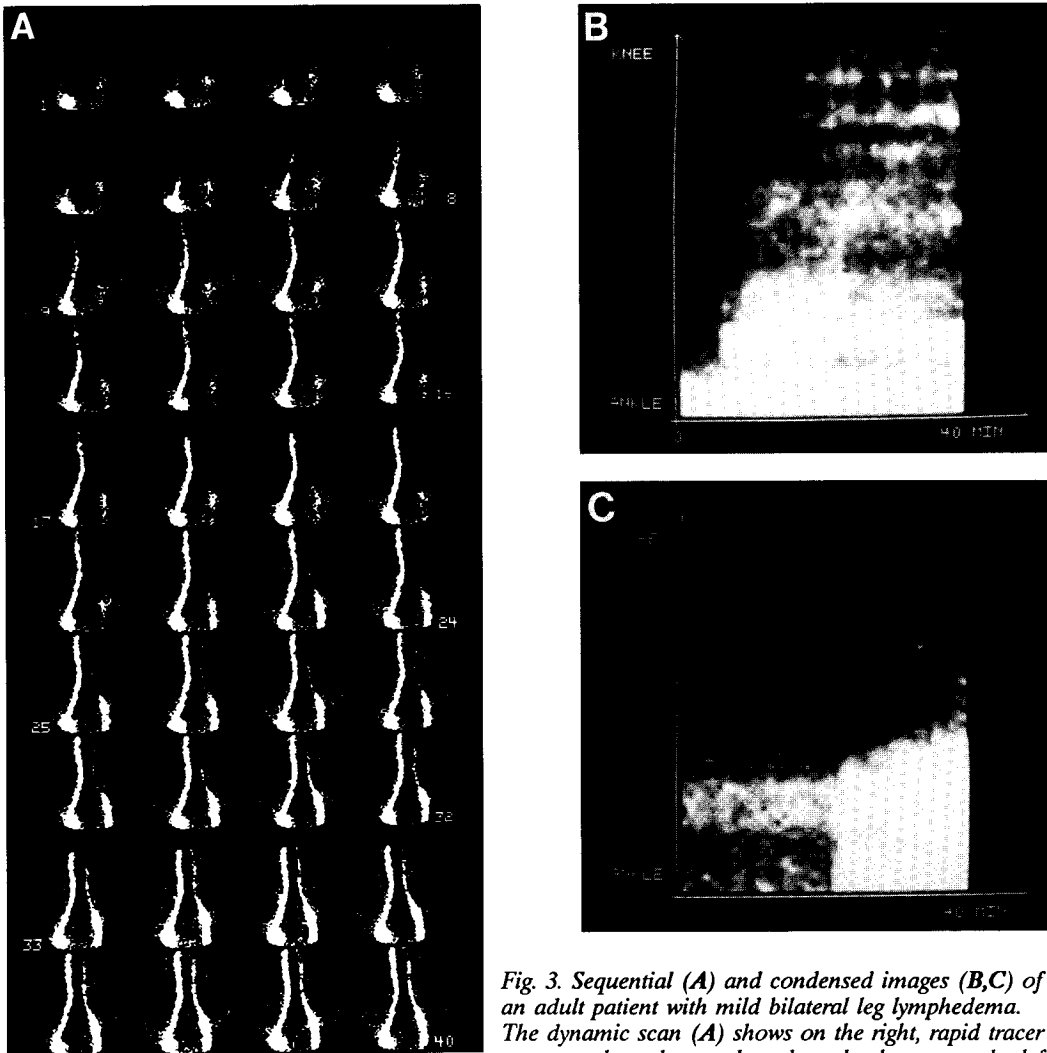
*Fig. 2. Sequential (A) and condensed images (B,C) of an adult patient with bilateral leg lymphedema (right greater than left) aggravated by chronic venous insufficiency. Whereas on the left side there is rapid cephalad migration of the tracer, on the right there is persistent localization at the injection site. These differences are accentuated in the condensed images. Whereas on the right (B) there is intense radioactivity at the injection site (broad horizontal band) but no ascending transport (lymphatic hypoplasia), on the left (C), there is an abrupt rise (within two minutes) with multiple vertical and horizontal tracer bands suggestive of hyperdynamic lymph flow (compare with normal condensed image, Fig. 1B).*

mal transit time and stasis).

#### Patient 4

A 33-year-old woman had bilateral lymphedema mainly of the left ankle and foot. The left ankle had been injured six years earlier. The dynamic sequential image (Fig. 4A) shows on the right after ten minutes inhomogenous tracer activity

distributed in lymphatic trunks and on the left promptly after injection localized distal radioactivity that persists largely unchanged. The condensed image on the right (Fig. 4B) displays two vertical activity areas surmounted by an area of denser radioactivity between 14 and 23 minutes and between 36 and 40 minutes, respectively. The distal bands represent two successive tracer influxes (abnormal



*Fig. 3. Sequential (A) and condensed images (B,C) of an adult patient with mild bilateral leg lymphedema. The dynamic scan (A) shows on the right, rapid tracer transport through an enlarged trunk whereas on the left*

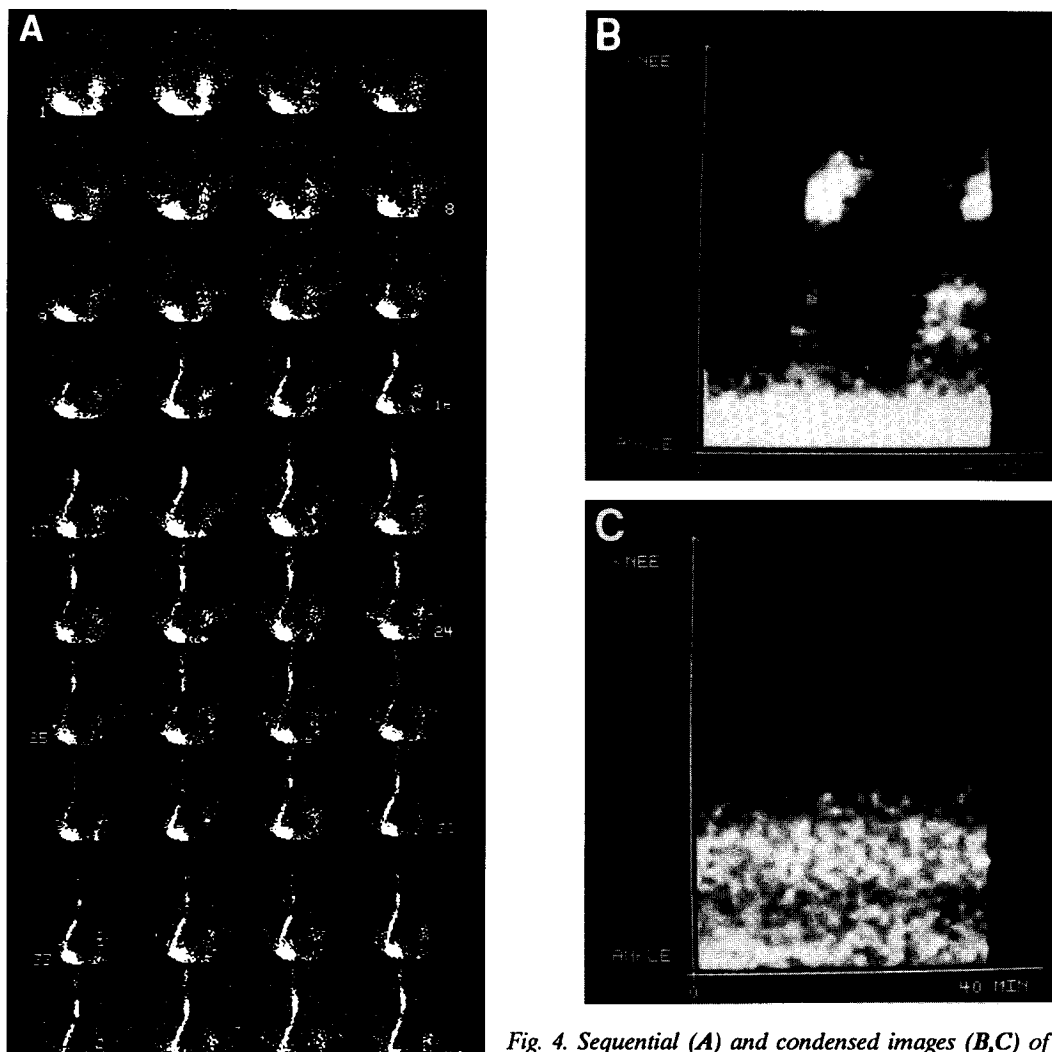
*lymphatic transport is delayed. These differences are accentuated on the condensed images which on the right (B) depicts an "enhanced pattern" with prompt tracer transport and prominent horizontal and vertical activity bands. A notable horizontal band in the lower leg suggests some degree of stagnancy (hypoplasia). By comparison on the left leg (C) there is little upward transport (prominent horizontal band) followed at 25 minutes by a sudden influx toward the knee (abnormal transit time and stasis).*

lymph propulsion). The condensed image of the left leg (Fig. 4C) shows slight tracer activity surmounted by a horizontal radioactive band. No significant tracer activity is seen in the upper two-thirds of the leg (lymphatic insufficiency without collateral transport).

#### DISCUSSION

##### Condensation of dynamic sequential

images of isotopic lymphography has the select advantage of a single image while concentrating quantitative data from a large family of time-activity curves. The reported patients illustrate that condensed image processing (CIP) improves the diagnostic utility of isotopic lymphographic data by depicting successive tracer (lymph) influxes from the injection site, by demonstrating and localizing lymph stasis, and by displaying abnormal lymph



*Fig. 4. Sequential (A) and condensed images (B,C) of an adult patient with bilateral lymphedema mainly of the left ankle and foot. The dynamic image (A) shows inhomogeneous activity moving upward on the right whereas on the left distal radioactivity remains localized. The condensed images reveal, however, on the right (B) two bursts of "vertical" activity between 14 and 23 minutes and between 36 and 40 minutes suggestive of abrupt and abnormal lymph propulsion. On the left, however, (C) tracer activity remains "horizontal" with little transport into the upper two-thirds of the leg (lymphatic insufficiency).*

propulsion. The slope of tracer activity on the condensed image reflects the tracer (lymph) transit time.

The condensed images in hyperdynamic lymphatic insufficiency are especially noteworthy, suggesting discontinuous lymph transport with propulsion "bursts." The main factor thought responsible for lymph transport is intrinsic contractility of the lymphatic trunks (16,17). Olszewski documented spontaneous

rhythmic contraction of prenodal lymphatics in man by intralymphatic pressure and lymph flow recordings. Lymph flow occurs primarily during the lymphatic pulse waves (17). Elevated venous pressure further increases lymph flow (18,19) with lymph flow rate directly proportional to the rate of lymphatic contractions (17,20). Where lymph production exceeds the rate of lymph return (dynamic insufficiency) the condensed image displays a

set of prominent bands. Although speculative, the horizontal bands may reflect the stationary nature of the contraction wave with individual lymphangions filled with stagnant lymph. The vertical bands, on the other hand, may signify synchrony of lymphangion contraction rhythm and the recording time rate or in effect the propulsion of lymph between contiguous lymphangions. In patients with normal lymphatics, for example, multiple vertical and horizontal bands are not seen (personal observations). In comparison with patients with accelerated lymph dynamics, normal subjects may have minimal volumes of lymph and the relative sensitivity of the method or asynchrony of lymphatic propulsion may preclude the appearance of horizontal and vertical bands. The mere appearance of multiple horizontal and vertical bands, therefore, probably reflects hyperdynamic lymph flow.

In conclusion, condensed imaging processing provides a synthesized single image display of the temporal and spatial distribution of the sequential recordings of isotopic lymphography. In patients with hyperdynamic lymphatic insufficiency, CIP allows abnormalities to be detected that are not readily apparent by standard analysis. Further experience is necessary, however, to evaluate fully the varied patterns of lymphedema.

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