DETECTION OF HUMAN CARDIAC ACTIVITY AT APEX REGION BY LASER SPECKLE

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ABSTRACT

Time average speckle interferometric technique has been used to obtain the displacement pattern over the chest rgion of healthy subjects. It shows that the displacements, over the apex region, caused by the heart movement, differ significantly from that of the corresponding region on the right side of the chest.

INTRODUCTION

WHEN an optically rough surface is illuminated by a coherent light as that from a laser, the surface has a grainy or speckled appearance. The speckles, which are due to an interference phenomenon, are localized in space and move with the movement of the eye.

Leser speckle interferometry provides a non-contact technique which has been used for various engineering applications such as for measuring displacement, strain and the roughness of plane surface[1-5]. The application of laser speckle in medicine is still in infancy. Zi,i et al.[6] using double pulsed ruby laser holography observed the patterns of motion of the surface of a human chest during inhalation. Hok et al.[7] applied a similar technique for studying the patterns of chest wall motion due to heart action. But these techniques provide only a qualitative information of the chest wall movement. The present technique is much simpler than the ruby laser holographic technique and provides a quantitative assessment of the displacement pattern over the chest wall caused by the cardiac movement.

METHOD

The recording of time average specklegram was carried out in the Fourier transform plane [Fig. 1 (a)]. A healthy subject was asked to sit in an upright position on a chair. For recording the speckle pattern, the subject was asked to inhale and to exhale and then to hold the breath, so that during the recording of the chest movement the abdomen wall did not suffer any displacement. To overcome the body movements during the experiment the subject was firmly fastened to the chair with a belt.

A 5·0 mw He–Ne laser (Polytec—Germany) of wavelength 632·8 nm was used as a light source. The beam was expanded by a beam expander to illuminate an area over the apex region on the left side of the chest. A camera loaded with Agfa-Gevaert Scientia

10E75 photographic plate was placed in the Fourier plane of a large aperture convex lens of focal length 15·0 cm [Fig. 1 (a)]. The heart beat of the subject was approximately 70 beats/min. Accordingly the exposure time was of the order of 5 seconds, as for time average speckle interferometry the exposure time should be longer than one second. This plate was processed using D19 developer and DA163 fixer.

Using the same technique, another speckle pattern to compare with that of the apex region was recorded on the right side of the chest wall. The distance of the region from the midline was the same as that of the apex region on the left side of the chest.

The recorded speckle pattern was analyzed by the point-wise method [Fig. 1 (b)]. The speckle interferogram was mounted on an upright, provided with hori-

B = BEAM EXPANDER
S = SUBJECT
L = LENS
P = PHOTOGRAPHIC PLATE

(a)

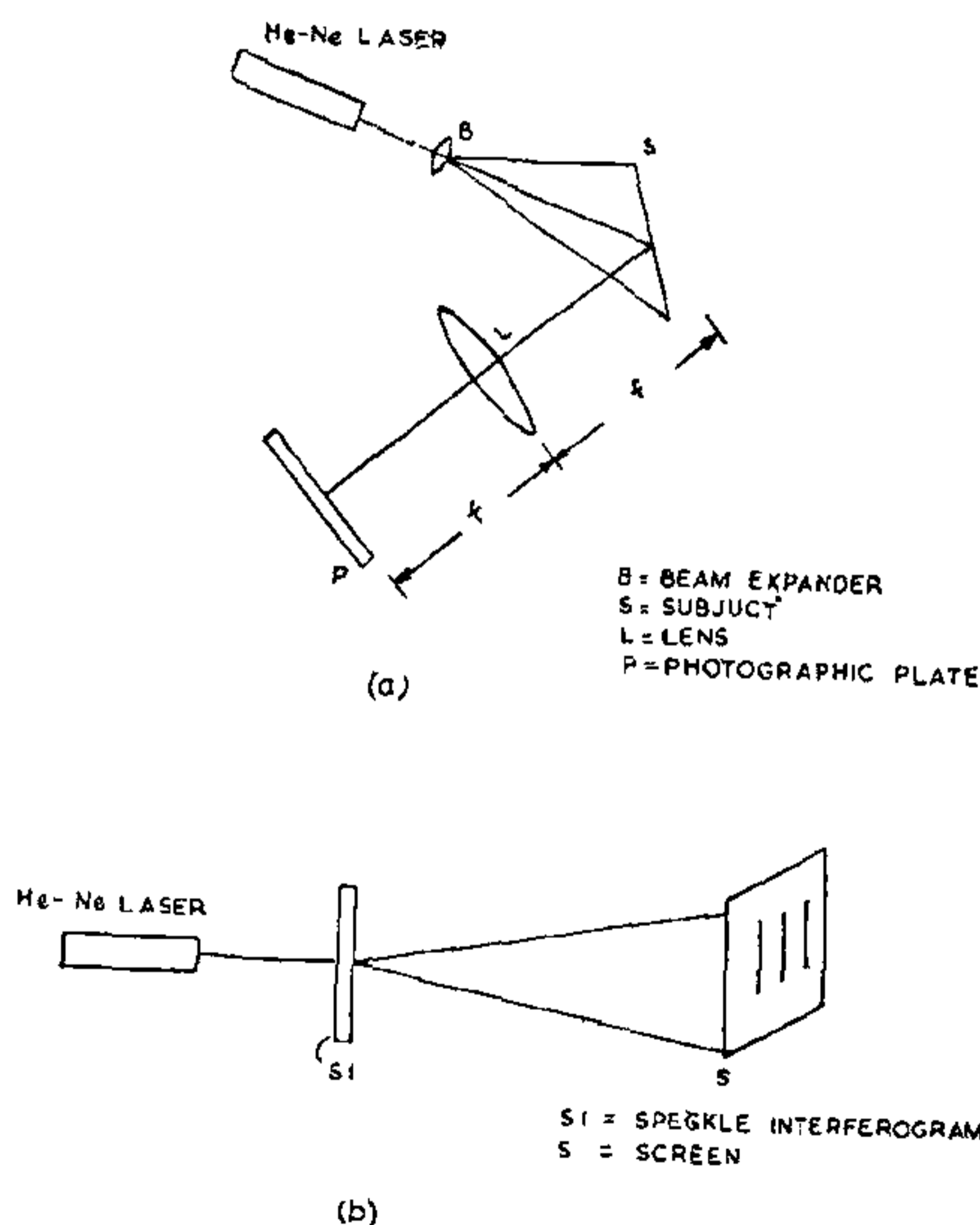SI = SPECKLE INTERFEROGRAM
S = SCREEN

(b)

FIG. 1 (a). Schematic of the experimental arrangement to obtain speckle interferogram (specklegram). (b) Schematic for the analysis of speckle interferogram

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zontal and vertical movement with vernier and head scale graduation. The plate was scanned by illuminating it with a laser beam. The fringe pattern obtained showed Young's fringes (Fig. 2), formed due to the orthogonal component of the displacement of the surface with respect to the film plate. The position of the laser beam on the plate and the width of the fringes over this region 'β' were measured. The displacement d at the corresponding point was calculated by

$$d = \lambda D / \beta$$

where λ—wavelength of the laser beam, D—distance between speckle interferogram and screen and β—fringe width.

The fringe patterns indicated over the apex region and the equidistant region on the right side were similarly analyzed by the above method. The entire data were fed to an IBM 370/155 computer to calculate the displacements at various points and to plot the displacement *versus* position graphs for these regions.

RESULTS AND DISCUSSION

The cardiac cycle is characterized by the following events : Between beats, the heart mechanically rests and this is known as the period of diastole. During diastole the heart assumes its maximum size and fills with oxygenated blood coming from the lungs and the venous blood coming from the body. The heart's period of mechanical activity is that during which pumping of blood into the body for circulation and into the lungs for oxygenation takes place.

The systole is initiated by contraction of the muscles surrounding the atria, which propel additional blood

FIG. 2. Young's fringes at displacement = 0·25 mm.

into the ventricles. The ventricles then begin to contract, thereby, causing a rise in pressure within the ventricles. This increased pressure closes the atrioventricular valves, and with further contraction the pressure continues to rise. As soon as the pressures corresponding to systemic and pulmonary circulation are exceeded, a phase of ventricular ejection begins. The pulmonary valve is forced open and blood is supplied to pulmonary circulation by right ventricle. Likewise the aortic valve is forced open and blood is squeezed into the aorta and thence into systemic circulation.

Depending on the mechanical activity of the various parts of the heart, the regions adjacent to it and the tissue structure of the chest wall over this region show a varying pattern of the displacements, of varying magnitudes from micron to millimeter. The contractile activity of the apex region is significantly higher in comparison with any other region of the heart and thus corresponds to the region of higher activity on the chest wall[8,9].

Figure 3 (a) shows the relationship between displacement and position over the apex region. The position at 2·4 cm on the plot indicates the extreme end of the apex region. This pattern shows the presence of the complex movements over this region. Fig. 3 (b) indicates a similar relationship of a region, on the right side of the chest wall. This shows that the activity on the right side is considerably less than that on the left side. This could be attributed to the movements of the heart chambers which are partly positioned on the right side of the midline.

Many investigators have used the phono- and mechano-cardiography technique to determine the vibrations, produced by heart action, at the chest wall[10-12]. The contribution of Verburg[13-15] for the measurement of the displacements over the chest region, using accelerometers, needs mentioning. By using the digital filtering technique, the values of displacements from accelerations are obtained. The displacement peaks at apex region have their distinct nature as compared to that at other regions of the chest over the heart. Similar results by Hok *et al*[7], using ruby laser holographic technique, have also been reported. These results show a qualitative agreement with our results, but a quantitative comparison, due to non-availability of the required data from their work, could not be carried out.

The results, reported here, are reproducible and show a slight variation in the displacement pattern with the variation of the stature of the subjects. These observations also indicate that the activity in the apex region is strongly defined by the pressures in the ventricles during the various phases of the cardiac cycle. Further experiments in order to find a corre-
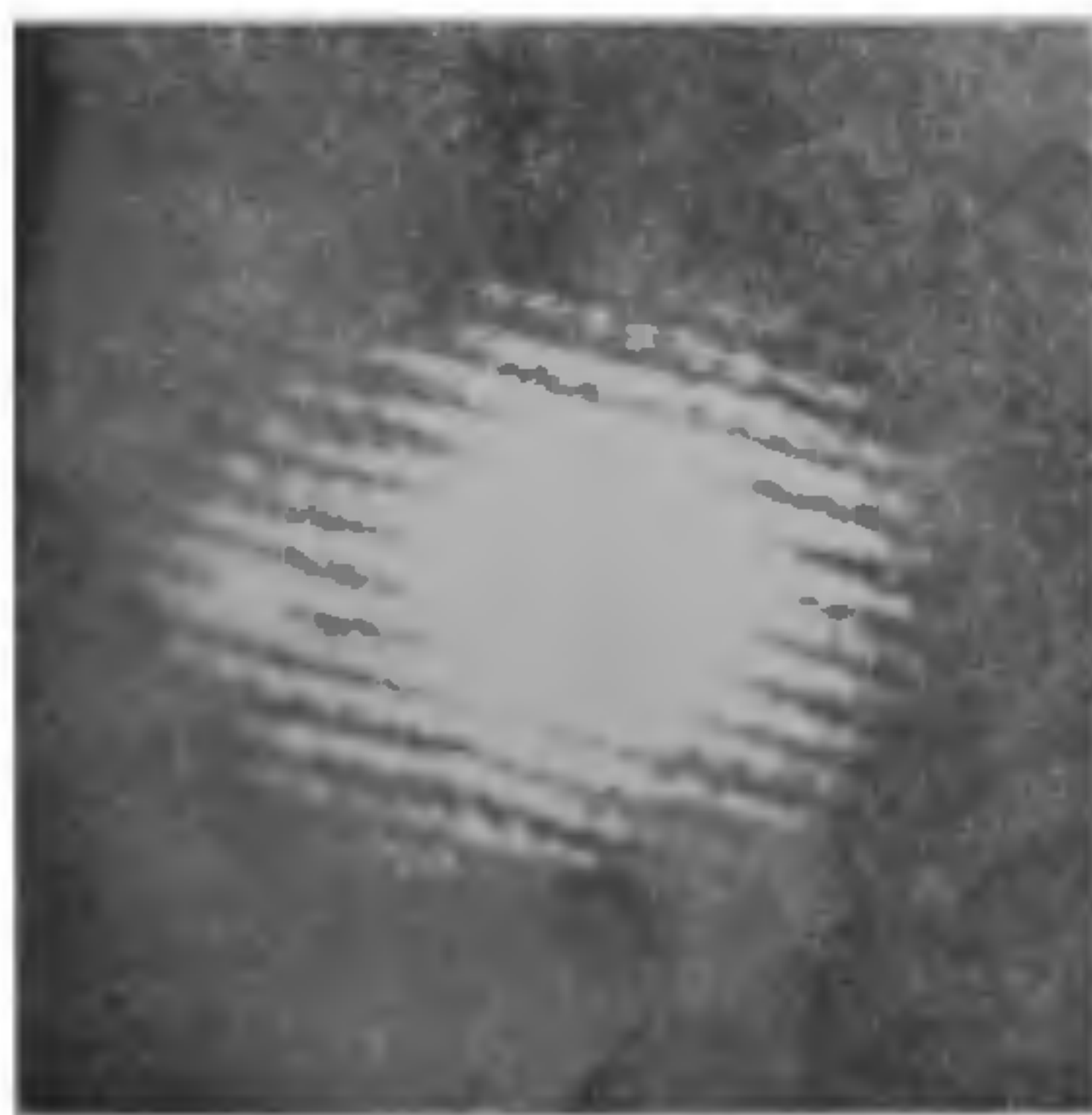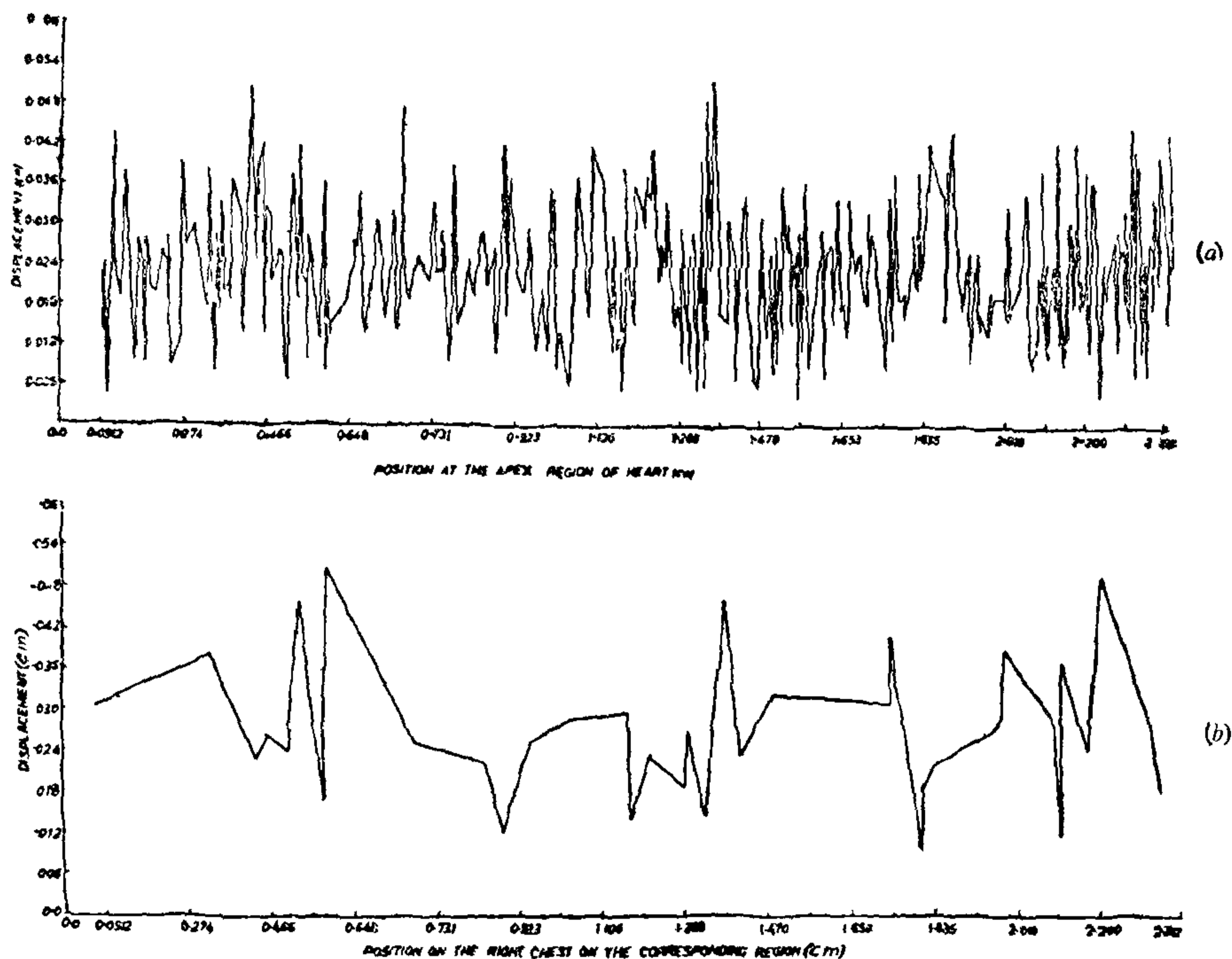
FIG. 3. Displacement *vs* position on the chest wall.   (*a*) Over the apex region,   (*b*) Corresponding region of the right side.

lation between cardiac activity and displacement pattern, in health and disease, are in progress.

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