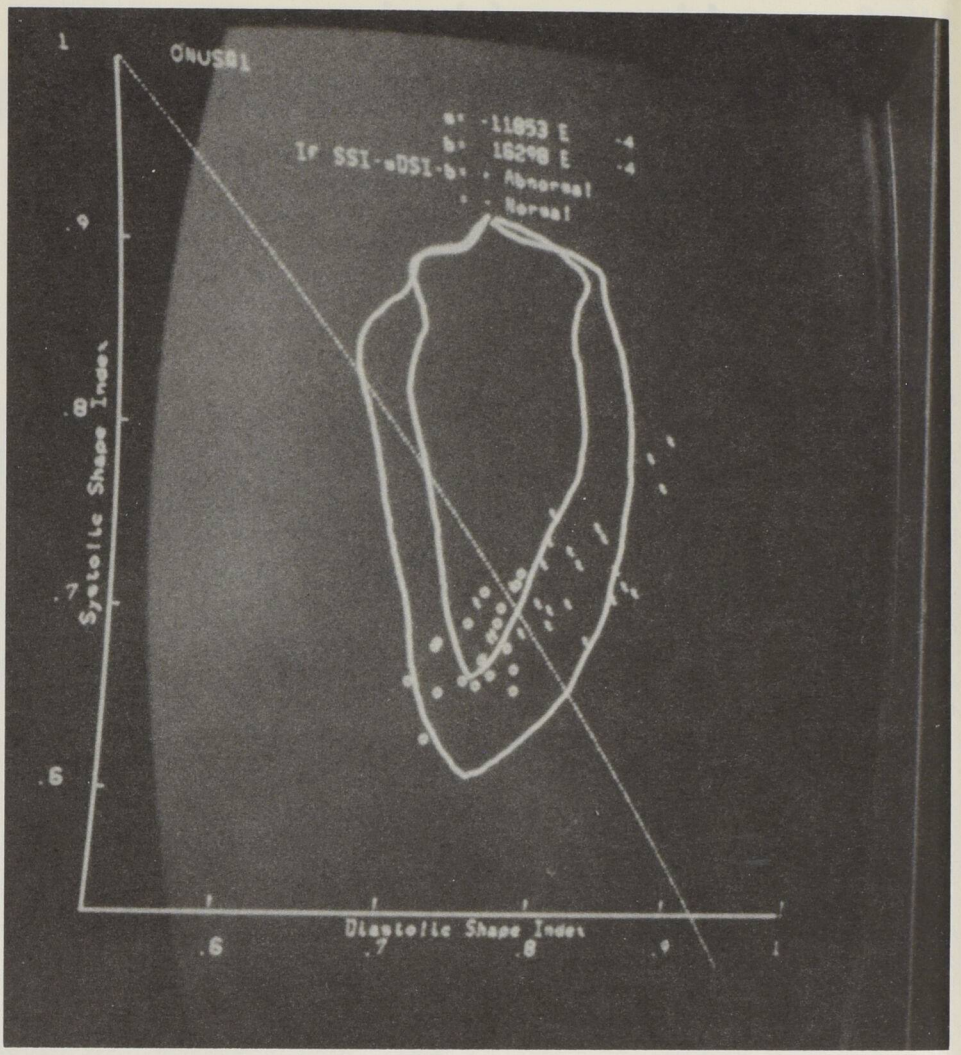
which, on contraction, pumps the oxygen-enriched blood throughout the body. Consequently, a quantification of the left ventricular function would increase a cardiologist's confidence in assessing the damage and, therefore, in judging the appropriate treatment.

The obvious solution to the quantitation problem according to Dr. B. C. Morton, a cardiologist with the University of Ottawa Cardiac Unit at the Ottawa Civic Hospital, was to use a computer facility capable of handling the graphic information contained in the X-rays of the left ventricle (i.e. angiograms) and converting it into a numerical analysis. With this thought in mind he approached National Research Council engineer Theodore Shepertycki, of the Computer Graphics Section in the Division of Electrical Engineering.

Mr. Shepertycki's first approach to the problem was to establish a computer program that could calculate ventricular function — specifically its capacity for pumping blood to the tissues. "It was known that a normal left ventricle ejects 66 per cent of the total blood in the chamber with each pumping action," states Mr. Shepertycki. "So, we expected that patients who had coronary artery disease with impaired left ventricular function would have ejection volumes below the normal level."

The procedure for calculating ventricular ejection volumes begins by obtaining X-ray pictures of the left ventricle walls in a serial time frame. The two frames representing the maximum and minimum ventricular expansion are selected and with the aid of a calibration grid their volumes calculated by a computer with an attached digitizing tablet and a computer display cathode ray tube (CRT). As the silhouettes of the left ventricle are traced on the digitizing tablet, the profiles are registered in the computer and displayed on the CRT monitor. The ejected volume is almost instantaneously calculated by a cross-section multiple slice method and is also displayed on the CRT.

"This procedure was applied to the angiograms of a variety of heart patients and, as expected, some had ejection fractions below the normal level," explains Mr. Shepertycki. "But we quickly discovered that there was a group of patients which had been diagnosed to be suffering from coronary artery disease, but according to our calculations still had normal ejection fractions." In this group the disease, presumably, had not yet progressed. Although a part of the left ventricular wall was not contracting properly the remaining muscle took up the slack to maintain a normal blood output. Interestingly, when the angiograms of the relaxed and contracted stage are superimposed the damaged wall segment and the area which compensates are both distinguishable.



Bruce Kane, NRC/CNRC

The image of a heart portrayed by computer. **Simulation informatique d'un cœur.**

"At this stage we realized that we had to increase the sophistication of the technique," states Mr. Shepertycki. "We wanted a more sensitive index, to identify those patients with normal ejection fractions but with abnormal left ventricular wall motion due to coronary artery disease." This refinement was achieved by using a simplified 3-dimensional computer model of the left ventricle in a calculation which more aptly defined its functional state. A formula was used to calculate a "shape index factor" which was defined as the ratio of the left ventricular volume to the volume of a sphere having the same surface area as the left ventricle. This method was then used to calculate the shape index factors for both the minimum and maximum expansion of the left ventricle for a selected group of patients all suffering from coronary artery disease but with normal ventricular ejection volumes. These patients were divided into two groups depending on whether, in Dr. Morton's opinion, they did or did not exhibit normal ventricular wall motion. When the calculated factor for the ventricle in the expanded state was plotted against the factor for the contracted state, the two groups of individuals clustered into the appropriate normal and abnormal categories. That is the method which successfully revealed those patients with damaged ventricular wall tissue even though their hearts pumped the normal amount of blood.

With the aid of such computer graphic techniques and their future refinements, cardiologists will be able not only to better assess the nature and extent of the disease, but also gauge the success of their surgical procedures. □

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