

[54] **METHOD FOR DETERMINING BLOOD FLOW THROUGH A NARROWED ORIFICE USING COLOR DOPPLER ECHOCARDIOGRAPHY**

[75] **Inventors:** **Julius M. Gardin**, Long Beach, Calif.; **Toshio Ogawa**, Tokyo, Japan; **Toshinori Utsunomiya**, Santa Ana; **Hoang A. Tang**, Orange, both of Calif.

[73] **Assignees:** **Hitachi Medial Corp.**, Tokyo, Japan; **The Regents of the University of California**, Oakland, Calif.

[21] **Appl. No.:** **325,562**

[22] **Filed:** **Mar. 17, 1989**

[51] **Int. Cl.⁴** **A61B 8/00**

[52] **U.S. Cl.** **128/661.1; 73/861.25**

[58] **Field of Search** **128/661.1; 73/861.25**

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,790,322 12/1988 Iinuma 128/661.1

OTHER PUBLICATIONS

H. Rouse, *Elementary Mechanics of Fluids*, John Wiley & Sons, Inc., New York, 1946, pp. 87-102.

K. Miyatake, M.D., et al., "Semiquantitative Grading of Severity of Mitral Regurgitation by Real-Time Two-Dimensional Doppler Flow Imaging Technique," *Journal of the American College of Cardiology*, vol. 7, No. 1, Jan. 1986, pp. 82-88.

Brian Hoit, et al., "Acceleration of Blood Flow Proximal to the Point of Systolic Anterior Motion in Hypertrophic Obstructive Cardiomyopathy: Demonstration of the Venturi Effect by Color Flow Mapping Doppler," *Circulation*, vol. 74, Supp II, No. 4, Oct. 1986, p. II-130.

Ann F. Bolger, et al., "Relationship of Color Doppler Jet Area to Flow Volume: Reliability and Limitations," *Circulation*, Abstracts of the 59th Scientific Sessions, vol. 74, Supp II, No. 4, Oct. 1986, p. II-216.

David J. Sahn, et al., "Factors Affecting Jet Visualization by Color Flow Mapping Doppler Echo: In Vitro Studies," *Circulation*, Abstracts of the 59th Scientific Sessions, vol. 74, Supp II, No. 4, Oct. 1986, p. II-271.

Frederick Helmcke, M.D., et al., "Color Doppler Assessment of Mitral Regurgitation with Orthogonal Planes," *Circulation*, vol. 75, No. 1, Jan. 1987, pp. 175-183.

(List continued on next page.)

Primary Examiner—Francis Jaworski
Attorney, Agent, or Firm—Knobbe, Martens, Olson & Bear

[57] **ABSTRACT**

A multi-gated pulsed wave color Doppler imaging system is used to provide accurate non-invasive measurements of liquid flow through a narrowed orifice by using the color Doppler to first measure the velocity of flow along an axis perpendicular to the orifice to provide a first image of the liquid velocity. The first image includes a two-color interface at locations in the image representing locations where the liquid velocity is equal to the aliasing velocity of the color Doppler imaging system. The distance from the two-color interface to the center of the orifice is measured and saved. A second image is obtained along an axis perpendicular to the first axis to represent the flow of liquid to the orifice from the perimeter of the orifice. The distance from a two-color interface to the center of the orifice in the second image is measured. The two measured dimensions are used to model a hemi-ellipsoidal surface proximal to the orifice wherein all points on the surface have the same isovelocity. The surface area is multiplied by the aliasing velocity to obtain the volume fluid flow rate through the orifice. A third image can also be obtained along a third axis perpendicular to the first and second axes and used to model an alternative hemi-ellipsoidal isovelocity surface. In a further alternative, a single image can be used to model a panshaped isovelocity surface.

7 Claims, 13 Drawing Sheets

