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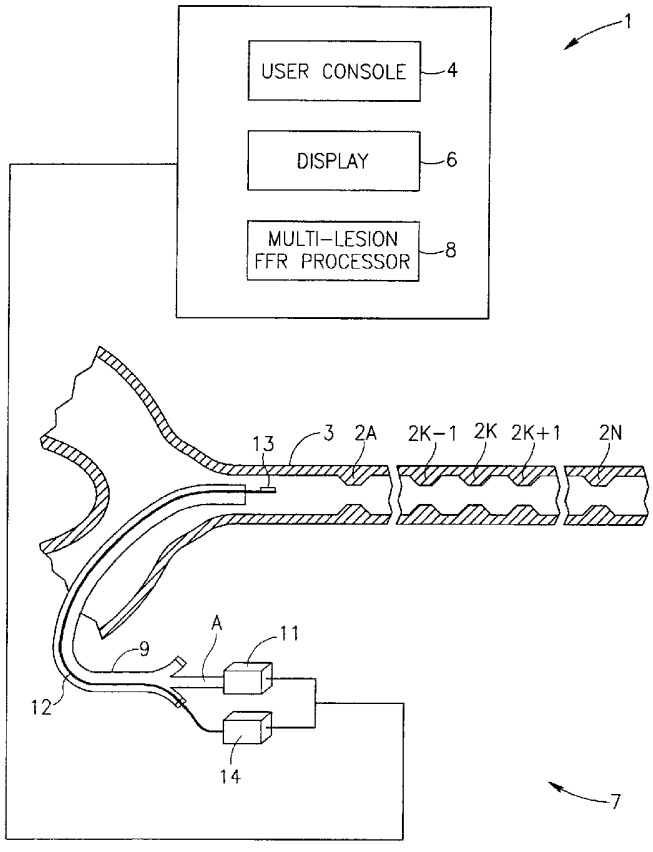
(54) Title: A SYSTEM FOR DETERMINING THE INDIVIDUAL FFR VALUES FOR THE LESIONS OF A MULTI-LESIONED BLOOD VESSEL, MULTI-LESION FFR PROCESSOR THEREFOR, AND METHOD THEREFOR



(57) Abstract: A system for determining the individual Fractional Flow Reserve (FFR) values for the lesions of a multi-lesioned blood vessel during continuous blood flow therethrough, a multi-lesion FFR processor therefor, and a method therefor. The individual FFR value for a lesion of interest can be determined by one of two different approaches both requiring a hyperemic pressure measurement distal to the last lesion but one requiring additional pressure measurements at rest, and the other additional hyperemic pressure measurements.

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A SYSTEM FOR DETERMINING INDIVIDUAL FFR VALUES FOR THE LESIONS OF A MULTI-LESIONED BLOOD VESSEL, MULTI-LESION FFR PROCESSOR THEREFOR, AND METHOD THEREFOR

Field of the Invention

The invention relates to determining the values of intravascular hemodynamic parameters in general, and the individual Fractional Flow Reserve (FFR) values for the lesions of a multi-lesioned blood vessel in particular.

Background of the Invention

Vascular diseases are often manifested by reduced blood flow due to atherosclerotic occlusion of blood vessels due to the isolated lesion of a single-lesioned blood vessel or the multiple typically either two or three lesions of a multi-lesioned blood vessel. For single-lesioned blood vessels, clinical studies have shown that angioplasty may be avoided in most cases in which Fractional Flow Reserve (FFR) >0.75, and conversely should be considered for cases in which FFR<0.75 as described in "*Pressure-based simultaneous CFR and FFR measurements: understanding the physiology of a stenosed vessel*", Shalman, E. et al., Comput. Biol. and Med. 31 (2001) 353-363.

However, it has been found that the technique for determining the FFR value for the isolated lesion of a single-lesioned blood vessel is not applicable for determining the individual FFR value of a lesion of a multi-lesioned blood vessel due to hemodynamic interaction between its lesions as described in "*Coronary pressure measurement to assess the hemodynamic significance of serial stenoses within one coronary artery. Validation in humans.*" by Pijls NJH, et al., Circulation, 2000; 102:2371:2377, and "*Pressure derived fractional flow reserve to assess serial epicardial stenoses: theoretical model and animal validation.*" by De Bruyne B, et al., Circulation, 2000; 101:1840:1847. To overcome this

problem, the articles describe a technique requiring complete obstruction of a tandem-lesioned blood vessel with two lesions for obtaining a so-called wedge pressure denoted P_w for determining the individual FFR values of the two lesions, thereby limiting the analysis to after at least partial treatment of the lesioned blood vessel.

Summary of the Invention

Generally speaking, the present invention enables the determination of the individual FFR values for the lesions of a multi-lesioned blood vessel during the diagnostic stage prior to intervention by virtue of the determination being based on pressure measurements acquired during continuous blood flow therethrough. The pressure measurements include an aortic pressure measurement acquired proximal to the first lesion of a multi-lesioned blood vessel, pressure measurements proximal and distal to the k^{th} lesion of interest, and at least a hyperemic pressure measurement distal to the last lesion of the lesioned blood vessel. The pressure measurements proximal and distal to the k^{th} lesion of interest, and distal to the last lesion of a multi-lesioned blood vessel can be acquired with a pressure transducer of a pressure guide wire being deployed stationary at different positions therealong or alternatively they can be obtained during a so-called "*pullback*" procedure as described in *"Practice and Potential Pitfalls of Coronary Pressure Measurement"*, Pijs, N. H. J., et al., Catherterization and Cardiovascular Interventions 49:1-16 (2000).

Determining the individual FFR values of the lesions of a multi-lesioned blood vessel is preferably achieved by means of an intermediate parameter termed the partial FFR value (hereinafter denoted "$pFFR_k$") for the first k lesions of a multi-lesioned blood vessel defined as the ratio of the maximal hyperemic pressure P_k distal to the k^{th} lesion divided by the maximal hyperemic aortic pressure P_0, namely, $pFFR_k = P_k/P_0$, whereupon the desired individual FFR_k value of a k^{th} lesion of a multi-lesioned blood vessel is calculated from the following FFR relationship developed hereinbelow:

$$\frac{1-FFR_k}{FFR_k^2}\alpha\frac{pFFR_{k-1}-pFFR_k}{pFFR_n^2}$$

where $pFFR_k$ is its partial FFR value, and $pFFR_{k-1}$ and $pFFR_n$ are respectively the partial FFR values of the k-1th and the last lesions of the multi-lesioned blood vessel. The hyperemic aortic pressure P_0 can be equally and is preferably acquired at rest since aortic pressure is substantially equal both at rest and during hyperemia.

It is well known that the pressure gradient Δp across a kth lesion of a multi-lesioned blood vessel is proportional to the square of the flow therethrough:

$$\Delta p_k = p_{k-1} - p_k = \alpha_k Q^2 \qquad \text{Eqn. (1)}$$

where the constant α_k is a function of its geometry, and Q is the flow through the blood vessel as discussed in articles: "*Simultaneous assessment of coronary flow reserve and fractional flow reserve with a novel pressure-based method*", Gruberg, L., et al., Journal of Interventional Cardiology, 2000; 13:323-329, and the aforementioned *"Pressure-based simultaneous CFR and FFR measurements: understanding the physiology of a stenosed vessel"*, Shalman, E., et al., Comput. Biol. Med. 31 (2001) 353-364.

Substituting $Q = Q_{max}\, pFFR_n$ into $\Delta p_k = P_{k-1} - P_k = \alpha_k Q^2$, the following equation for the kth lesion of a multi-lesioned blood vessel is obtained:

$$\Delta P_k = P_{k-1} - P_k = \alpha_k Q_{max}^2\, pFFR_n^2$$

Dividing this equation by the hyperemic aortic pressure P_0, substituting $pFFR_{k-1}$ for P_{k-1}/P_0 and $pFFR_k$ for P_k/P_0, and dividing both sides by the term $pFFR_n^2$ renders the following equation:

$$\frac{pFFR_{k-1}-pFFR_k}{pFFR_n^2} = \frac{\alpha_k Q_{max}^2}{P_0} \qquad \text{Eqn. (2)}$$

For the case of a single lesioned blood vessel, k=n=1 such that $pFFR_{k-1}=P_0/P_0=1$, and $pFFR_k = pFFR_n = FFR_k$ which on substitution into Eqn. (1) leads to

$$\frac{1-FFR_k}{FFR_k^2}=\frac{\alpha_k^2\,Q_{max}^2}{P_0} \qquad \text{Eqn. (3)}$$

Equating the left hand sides of the Eqns. (2) and (3), leads to the following FFR quadratic equation for determining the individual FFR value for a k^{th} lesion of a multi-lesioned blood vessel:

$$\frac{1-FFR_k}{FFR_k^2}=\frac{pFFR_{k-1}-pFFR_k}{pFFR_n^2} \qquad \text{Eqn. (4)}$$

Eqn. (4) requires at least two hyperemic pressure measurements for determining the individual FFR value for a k^{th} lesion of a multi-lesioned blood vessel depending on its location i.e. k=1, 2, .., n, and the number of lesions n. Since obtaining hyperemic pressure measurements is complicated and time consuming, an alternative approach for solving the FFR quadratic equation is preferable dependent on finding a suitable term to replace the righthand nominator, namely, $pFFR_{k-1}$-$pFFR_k$. From Eqn. (1), $\Delta P_k=P_0-P_n=\alpha_k Q_{hyp}^2$ and $\Delta p_k=p_0-p_n=\alpha_k Q_{rest}^2$ such that on re-arranging terms $\Delta P_k=\Delta p_k\,(P_0-P_n)/(p_0-p_n)$ where capital case P and small case p respectively denote hyperemic pressure measurements, and pressure measurements at rest. Also, since $\Delta p_k=p_{k-1}-p_k$, and $pFFR_{k-1}-pFFR_k = P_{k-1}/P_0 - P_k/P_0 = \Delta P_k/P_0$, then $pFFR_{k-1}-pFFR_k = \Delta P_k/P_0$ where $\Delta P_k=(p_{k-1}-p_k)\,(P_0-P_n)/(p_0-p_n)$.

Brief Description of the Drawings

In order to understand the invention and to see how it can be carried out in practice, preferred embodiments will now be described, by way of non-limiting examples only, with reference to the accompanying drawings, in which similar parts are likewise numbered, and in which:

Fig. 1 is a block diagram of a system for determining the individual FFR values for the lesions of a multi-lesioned blood vessel;

Fig. 2 is a graph showing exemplary pressure waveforms of distal pressure measurements simultaneously acquired by a fluid filled pressure transducer and a pressure guide wire;

Fig. 3 is a flow diagram showing the steps of a method for determining the individual FFR value for a k^{th} lesion of a multi-lesioned blood vessel;

Fig. 4 is a graph showing a mean pressure pulse acquired distal to a lesion at rest before synchronization;

Fig. 5 is a graph showing the pressure pulse of Figure 4 after synchronization;

Fig. 6 is a graph comparing the individual FFR values for the lesions of tandem-lesioned blood vessels in nine human patients obtained using the single vasodilatation induction approach of the present invention with the individual FFR values obtained for the same nine patients using the aforementioned Pijls & DeBruyne technique; and

Fig. 7 is a graph comparing the individual FFR values for the lesions of the tandem-lesioned blood vessels in nine human patients obtained using the multi-vasodilatation induction approach of the present invention and the individual FFR values obtained for the same nine patients using the aforementioned Pijls & DeBruyne technique.

Detailed Description of the Preferred Embodiments

Figure 1 shows a system 1 for determining the individual FFR values for the lesions 2A, ..., 2K-1, 2K, 2K+1, ..., and 2N of a multi-lesioned blood vessel 3 for enabling the determination of the necessity of medical treatment of each lesion, and the type. The system 1 is under the control of a user console 4 including a display 6, and includes intravascular pressure measurement apparatus 7 for acquiring pressure waveforms both proximal to the lesions, and distal thereto. The system 1 further includes a multi-lesion FFR processor 8 programmed for calculating the individual FFR values for each k^{th} lesion where k=1, 2, ..., n. In a preferred embodiment of the present invention, the user console 4, the display 6 and the multi-lesion FFR processor 8 are embodied as a general purpose digital computer.

The intravascular pressure measurement apparatus 7 includes a guiding catheter 9 connected to a fluid filled pressure transducer 11 for acquiring pressure measurements outside of patient's body at position A for use as a reference signal. An exemplary guiding catheter 9 is the Ascent JL4 catheter commercially available from Medtronic, USA whilst an exemplary fluid filled pressure transducer 11 is commercially available from Biometrix, Jerusalem, Israel. The intravascular pressure measurement apparatus 7 also includes a pressure guide wire 12 with a pressure transducer 13 at its tip connected to a signal conditioning device 14 for acquiring hyperemic and non hyperemic pressure measurements along the blood vessel proximal and distal to the lesions 2. An exemplary pressure guide wire 12 is the PressureWire^{TM} pressure guide wire commercially available from Radi Medical Systems, Uppsala, Sweden whilst an exemplary signal conditioning device 14 is also commercially available from Radi Medical Systems.

With reference to Figures 2-5, the use of the system 1 for determining the FFR value for a k^{th} lesion of a multi-lesioned blood vessel is now described in connection with the single vasodilatation induction approach using the same notation as before, namely, capital case P denotes hyperemic pressure measurements and small case p denotes pressure measurements at rest:

The guiding catheter 9 is introduced into the multi-lesioned blood vessel 3 to location A proximal to the lesion 2A. The pressure guide wire 12 is introduced into the guiding catheter 9 such that its pressure transducer 13 is also proximal to the lesion 2A. The fluid filled pressure transducer 11 continuously acquires the aortic pressure for use as a baseline for correcting pressure measurements acquired by the pressure transducer 13 to compensate for various factors, for example, breathing, patient movement, and the like, which may influence the pressure measurements since they are not acquired simultaneously. The pressure guide wire 12 is advanced to positions proximal to the intermediate lesions, 2K-1, 2K, and 2K+1, and distal to the lesion 2N for acquiring pressure measurements thereat. Figure 2 illustrates pressure measurements simultaneously acquired by

the fluid filled pressure transducer 11 and the pressure transducer 13. The pressure measurement distal to the last lesion 2N is repeated after induction of vasodilatation by administration of a suitable vasodilatation medicament, for example, adenosin.

Upon acquiring the pressure measurements, the multi-lesion FFR processor 8 executes the following steps to determine the individual FFR value for a k^{th} lesion of interest:

Step 1: Calculate four amplification factors A_{k-1}, A_k, $A_{n(rest)}$, and $A_{n(hyperemic)}$ from the pressure measurement acquired by the pressure transducer 11 for normalization purposes. The subscripts of the amplification factors correspond to the location of the pressure transducer 13 along the blood vessel, namely, proximal and distal to the k^{th} lesion of interest, and distal to the last lesion at rest and at hyperemia. Each amplification factor is the ratio between the mean pressure measurement corresponding to the location of the pressure transducer 13 with respect to the aortic mean pressure.

Step 2: Separate the pressure measurement acquired by the pressure transducer 13 into four sets of discrete pulses, namely, each starting and ending with a local minimum, respectively proximal and distal to the k^{th} lesion of interest, and distal to the last lesion at rest and at hyperemia.

Step 3: Amplify the discrete pulses using the factors A_{k-1}, A_k, $A_{n(rest)}$, and $A_{n(hyperemic)}$, respectively, and synchronize them such that each pulse has the same period between its local minimum values using a technique known as Automatic Synchronization Transformation (AST). Figures 4 and 5 illustrate the same pressure pulse before and after synchronization, respectively.

Step 4: Calculate four series of mean pressure measurements p_{k-1}, p_k, p_n and P_n from the synchronized amplified pulses.

Step 5: Calculate values of $pFFR_{k-1}$-$pFFR_k$ where $pFFR_{k-1}$-$pFFR_k=\Delta P_k/P_0$ and $\Delta P_k=(p_{k-1}-p_k)\ (P_0-P_n)/(p_0-p_n)$ on the assumption that $P_0=p_0$, and $pFFR_n$ values where $pFFR_n=P_n/P_0$ also on the assumption that $P_0=p_0$.

Step 6: Calculate the FFR value for the k^{th} lesion of interest by solving the FFR quadratic equation:

$$\frac{1-FFR_k}{FFR_k^2} = \frac{pFFR_{k-1} - pFFR_k}{pFFR_n^2}$$

using the third largest values for each of $pFFR_{k-1}$-$pFFR_k$, and $pFFR_n$ from Step 6.

Figure 6 shows that the individual FFR values obtained using the above approach have a high correlation of about 0.92 with those obtained using the Pijls & DeBruyne technique for the same nine human patients.

The system 1 may alternatively be employed for determining the individual FFR values for the lesions of a multi-lesioned blood vessel by solving the FFR quadratic equation using multiple hyperemic pressure measurements. In this case, vasodilatation is repeatedly induced prior to pressure measurements taken proximal and distal to a k^{th} lesion of interest, and distal to the last lesion. The pressure measurements using the fluid filled pressure transducer 11 are also taken to use for baseline purposes as described hereinabove. Figure 7 shows that the individual FFR values obtained using the multiple vasodilatation induction approach of the present invention also have a high correlation of about 0.9 with those obtained using the Pijls & DeBruyne technique for the same nine human patients.

While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications, and other applications of the invention can be made within the scope of the appended claims. For example, pressure data may be mean pressures over a heartbeat, maximal diastolic pressures, and the like.

Claims:

1. A system for determining the individual Fractional Flow Reserve (FFR) value for a lesion of interest of a multi-lesioned blood vessel, the system comprising:

(a) intravascular pressure measurement apparatus for acquiring pressure measurements in the multi-lesioned blood vessel during continuous blood flow therethrough; and

(b) a multi-lesion FFR processor for determining the FFR_k value for a k^{th} lesion of the multi-lesioned blood vessel where k=1, 2, ..., n based on an aortic pressure measurement acquired proximal to the first lesion of the multi-lesioned blood vessel, pressure measurements proximal and distal to the k^{th} lesion, and at least a hyperemic pressure measurement distal to the last lesion of the multi-lesioned blood vessel.

2. The system according to claim 1 wherein said multi-lesion FFR processor determines the FFR_k value for the k^{th} lesion in accordance with the FFR relationship:

$$\frac{1-FFR_k}{FFR_k^2}\alpha\frac{pFFR_{k-1}-pFFR_k}{pFFR_n^2}$$

where $pFFR_k$ is its partial FFR value, and $pFFR_{k-1}$ and $pFFR_n$ are respectively the partial FFR values of the k-1^{th} and the last lesions.

3. The system according to claim 2 wherein $pFFR_{k-1}-pFFR_k=\Delta P_k/P_0$ and $\Delta P_k=\frac{p_{k-1}-p_k}{p_0-p_n}(P_0-P_n)$ where p_{k-1} and p_k are respectively pressure measurements proximal and distal to the k^{th} lesion at rest, P_0 and p_0 are aortic pressure measurements, and p_n and P_n are pressure measurements distal to the last lesion at rest and at hyperemia, respectively.

4. The system according to claim 2 wherein $pFFR_{k-1}=P_{k-1}/P_0$, $pFFR_k=P_k/P_0$ and $pFFR_n=P_n/P_0$ where P_{k-1} and P_k are respectively hyperemic pressure measurements proximal and distal to the k^{th} lesion, P_0 is an aortic pressure measurement, and P_n is a hyperemic pressure measurement distal to the last lesion.

5. The system according to claim 2 wherein the FFR relationship is as follows:

$$\frac{1-FFR_k}{FFR_k^2}=\frac{pFFR_{k-1}-pFFR_k}{pFFR_n^2}.$$

6. For use with intravascular pressure measurement apparatus capable of acquiring pressure measurements in a multi-lesioned blood vessel, a multi-lesion FFR processor for determining the individual Fractional Flow Reserve (FFR) value for a lesion of interest of a multi-lesioned blood vessel, the multi-lesion FFR processor operable to:

(a) receive pressure measurements acquired in the multi-lesioned blood vessel during continuous blood flow therethrough; and

(b) determine the FFR_k value for a k^{th} lesion of the multi-lesioned blood vessel where k=1, 2, ..., n based on an aortic pressure measurement acquired proximal to the first lesion of the multi-lesioned blood vessel, pressure measurements proximal and distal to the k^{th} lesion, and at least a hyperemic pressure measurement distal to the last lesion of the multi-lesioned blood vessel.

7. The multi-lesion FFR processor according to claim 6 and operable to determine the FFR_k value for the k^{th} lesion in accordance with the FFR relationship:

$$\frac{1-FFR_k}{FFR_k^2}\alpha\frac{pFFR_{k-1}-pFFR_k}{pFFR_n^2}$$

where $pFFR_k$ is its partial FFR value, and $pFFR_{k-1}$ and $pFFR_n$ are respectively the partial FFR values of the k-1th and the last lesions.

8. The multi-lesion FFR processor according to claim 7 wherein $pFFR_{k-1}$-$pFFR_k=\Delta P_k/P_0$ and $\Delta P_k=\frac{p_{k-1}-p_k}{p_0-p_n}(P_0-P_n)$ where p_{k-1} and p_k are respectively pressure measurements proximal and distal to the kth lesion at rest, P_0 and p_0 are the aortic pressure measurements, and p_n and P_n are pressure measurements distal to the last lesion at rest and at hyperemia, respectively.

9. The multi-lesion FFR processor according to claim 7 wherein $pFFR_{k-1}=P_{k-1}/P_0$, $pFFR_k=P_k/P_0$ and $pFFR_n=P_n/P_0$ where P_{k-1} and P_k are respectively hyperemic pressure measurements proximal and distal to the kth lesion, P_0 is an aortic pressure measurement, and P_n is a hyperemic pressure measurement distal to the last lesion.

10. The multi-lesion FFR processor according to claim 7 wherein the FFR relationship is as follows:

$$\frac{1-FFR_k}{FFR_k^2}=\frac{pFFR_{k-1}-pFFR_k}{pFFR_n^2}.$$

11. A method for determining the individual Fractional Flow Reserve (FFR) value for a lesion of interest of a multi-lesioned blood vessel, the method comprising the steps of:

(a) deploying intravascular pressure measurement apparatus for acquiring pressure measurements in the multi-lesioned blood vessel during continuous

blood flow therethrough; and

(b) determining the FFR_k value for a k^{th} lesion of the multi-lesioned blood vessel where k=1, 2, ..., n based on an aortic pressure measurement acquired proximal to the first lesion of the multi-lesioned blood vessel, pressure measurements proximal and distal to the k^{th} lesion, and at least a hyperemic pressure measurement distal to the last lesion of the multi-lesioned blood vessel.

12. The method according to claim 11 wherein step (b) includes determining the FFR_k value for the k^{th} lesion in accordance with the FFR relationship:

$$\frac{1-FFR_k}{FFR_k^2}\alpha\frac{pFFR_{k-1}-pFFR_k}{pFFR_n^2}$$

where $pFFR_k$ is its partial FFR value, and $pFFR_{k-1}$ and $pFFR_n$ are respectively the partial FFR values of the $k\text{-}1^{th}$ and the last lesions.

13. The method according to claim 12 wherein $pFFR_{k-1}\text{-}pFFR_k=\Delta P_k/P_0$ and $\Delta P_k=\frac{p_{k-1}-p_k}{p_0-p_n}(P_0-P_n)$ where p_{k-1} and p_k are respectively pressure measurements proximal and distal to the k^{th} lesion at rest, P_0 and p_0 are aortic pressure measurements, and p_n and P_n are pressure measurements distal to the last lesion at rest and at hyperemia, respectively.

14. The method according to claim 12 wherein $pFFR_{k-1}=P_{k-1}/P_0$, $pFFR_k=P_k/P_0$ and $pFFR_n=P_n/P_0$ where P_{k-1} and P_k are respectively hyperemic pressure measurements proximal and distal to the k^{th} lesion, P_0 is an aortic pressure measurement, and P_n is a hyperemic pressure measurement distal to the last lesion.

15. The method according to claim 12 wherein the FFR relationship is as follows:

$$\frac{1-FFR_k}{FFR_k^2}=\frac{pFFR_{k-1}-pFFR_k}{pFFR_n^2}.$$

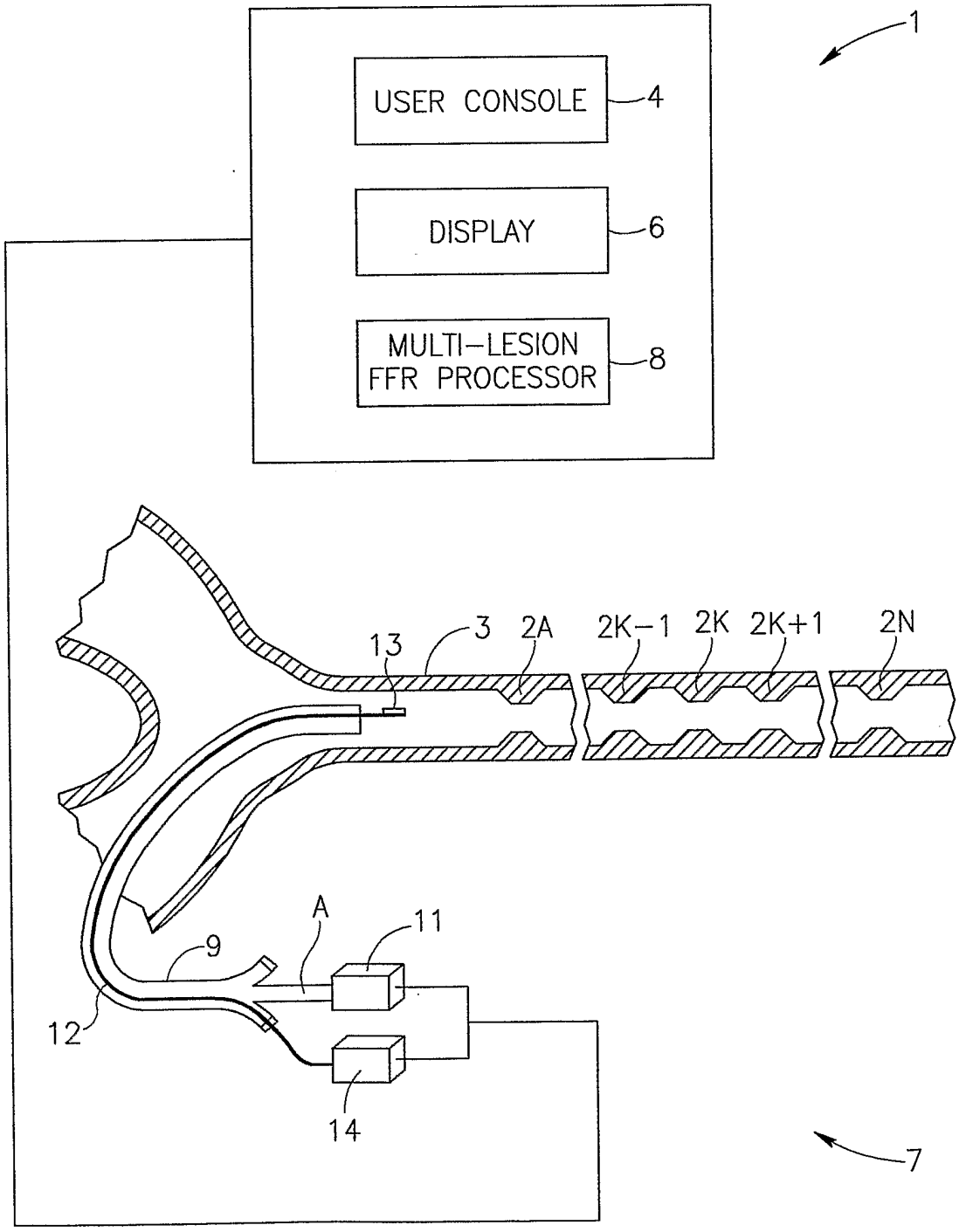
1
USER CONSOLE
4
DISPLAY
6
MULTI-LESION FFR PROCESSOR
8
13
3
2A
2K-1
2K
2K+1
2N
A
11
9
12
14
7

FIG.1

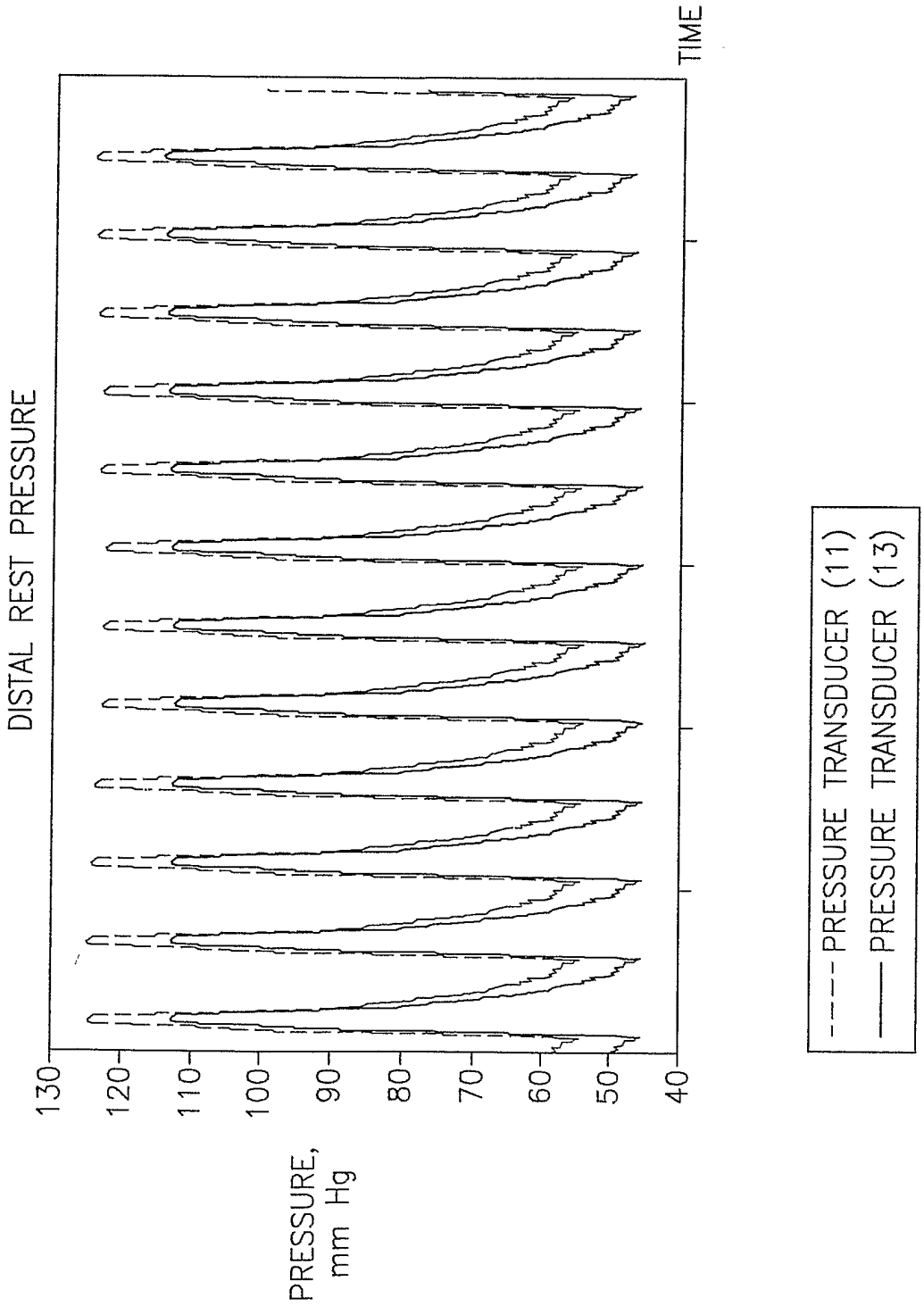
DISTAL REST PRESSURE
TIME
PRESSURE, mm Hg
130
120
110
100
90
80
70
60
50
40
PRESSURE TRANSDUCER (11)
PRESSURE TRANSDUCER (13)

FIG.2

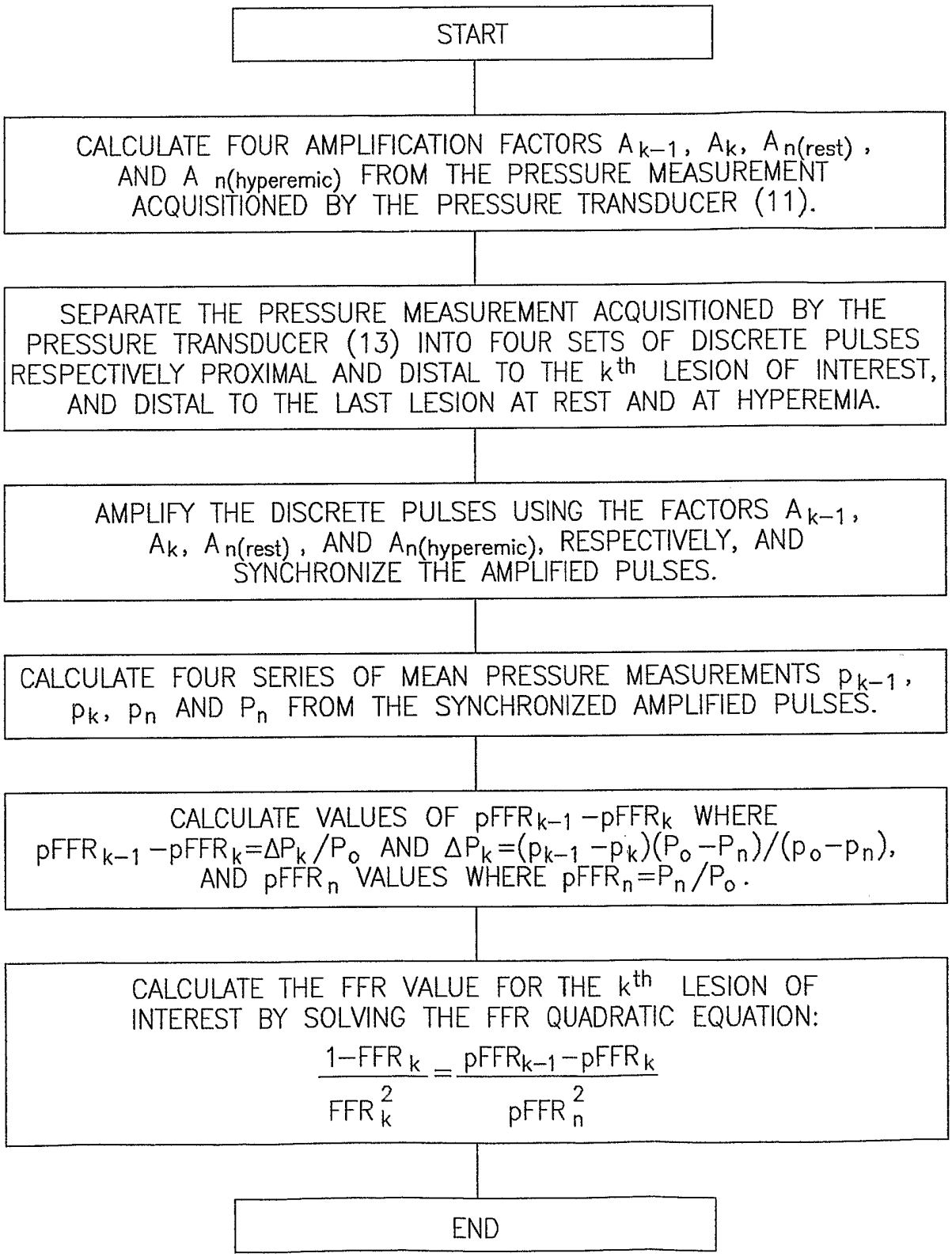
START
CALCULATE FOUR AMPLIFICATION FACTORS A_{k-1}, A_k, $A_{n(rest)}$, AND $A_{n(hyperemic)}$ FROM THE PRESSURE MEASUREMENT ACQUISITIONED BY THE PRESSURE TRANSDUCER (11).
SEPARATE THE PRESSURE MEASUREMENT ACQUISITIONED BY THE PRESSURE TRANSDUCER (13) INTO FOUR SETS OF DISCRETE PULSES RESPECTIVELY PROXIMAL AND DISTAL TO THE k^{th} LESION OF INTEREST, AND DISTAL TO THE LAST LESION AT REST AND AT HYPEREMIA.
AMPLIFY THE DISCRETE PULSES USING THE FACTORS A_{k-1}, A_k, $A_{n(rest)}$, AND $A_{n(hyperemic)}$, RESPECTIVELY, AND SYNCHRONIZE THE AMPLIFIED PULSES.
CALCULATE FOUR SERIES OF MEAN PRESSURE MEASUREMENTS p_{k-1}, p_k, p_n AND P_n FROM THE SYNCHRONIZED AMPLIFIED PULSES.
CALCULATE VALUES OF $pFFR_{k-1} - pFFR_k$ WHERE $pFFR_{k-1} - pFFR_k = \Delta P_k / P_o$ AND $\Delta P_k = (p_{k-1} - p_k)(P_o - P_n)/(p_o - p_n)$, AND $pFFR_n$ VALUES WHERE $pFFR_n = P_n / P_o$.
CALCULATE THE FFR VALUE FOR THE k^{th} LESION OF INTEREST BY SOLVING THE FFR QUADRATIC EQUATION:
$$\frac{1-FFR_k}{FFR_k^2} = \frac{pFFR_{k-1} - pFFR_k}{pFFR_n^2}$$
END

FIG.3

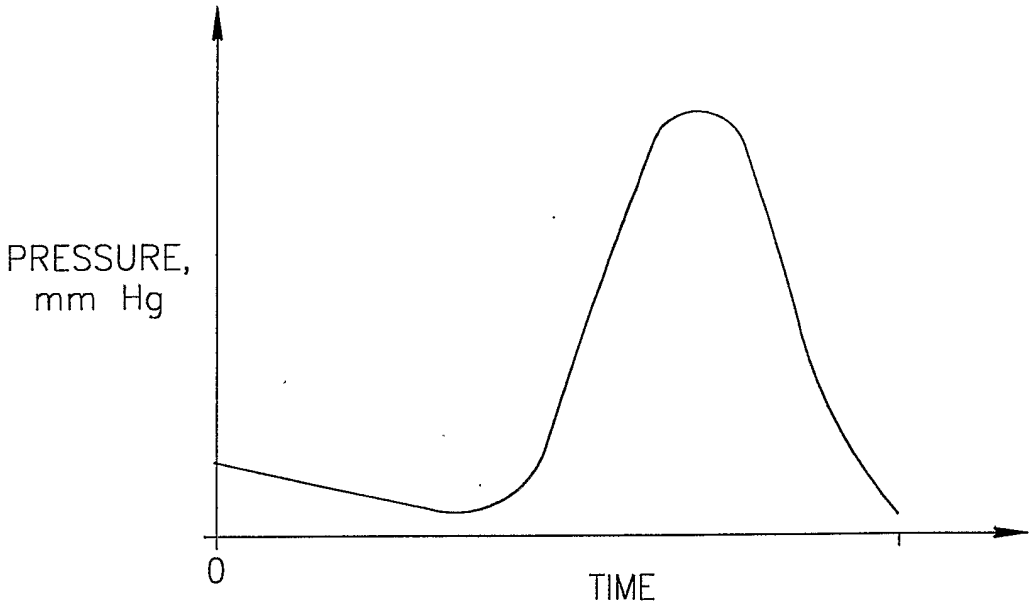

FIG.4

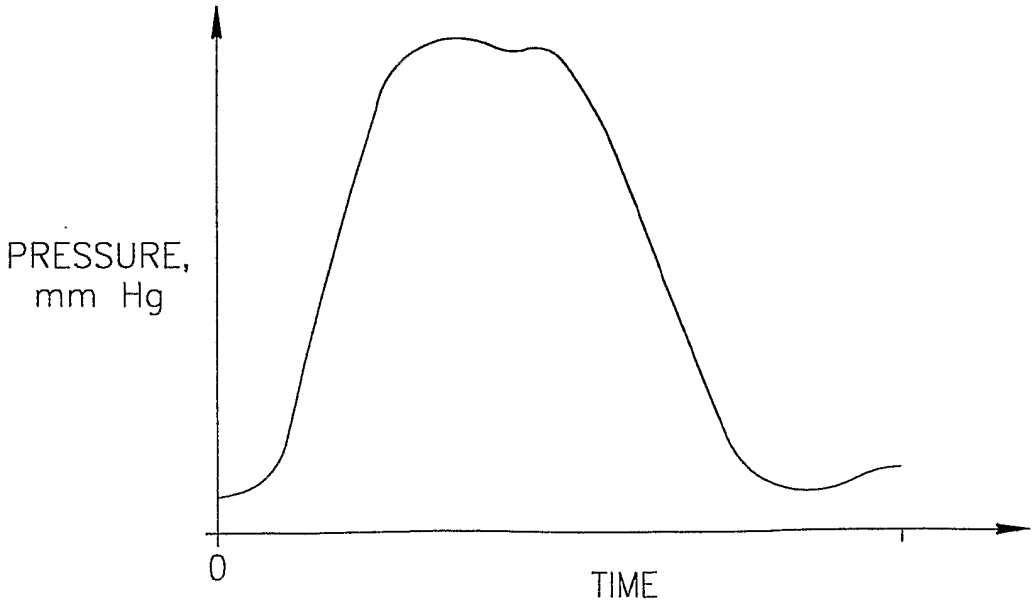

FIG.5

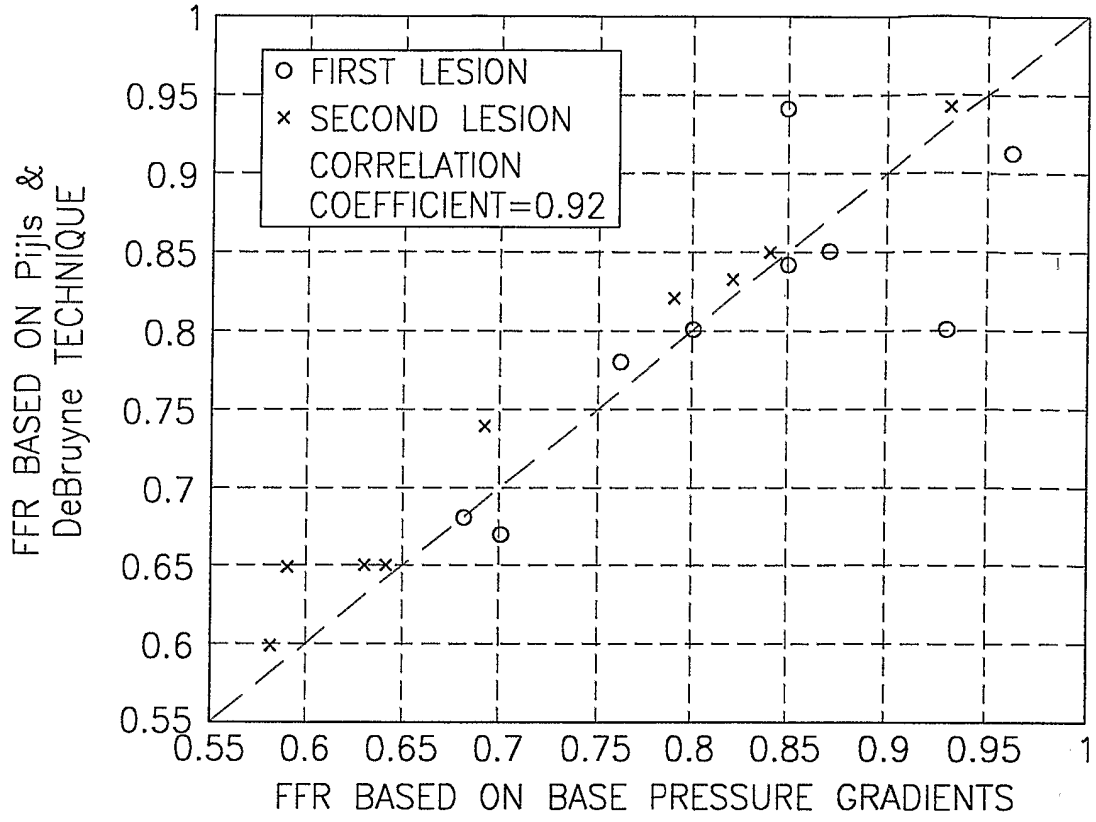
FIRST LESION
SECOND LESION
CORRELATION COEFFICIENT=0.92
FFR BASED ON Pijls & DeBruyne TECHNIQUE
FFR BASED ON BASE PRESSURE GRADIENTS
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95 1

FIG.6

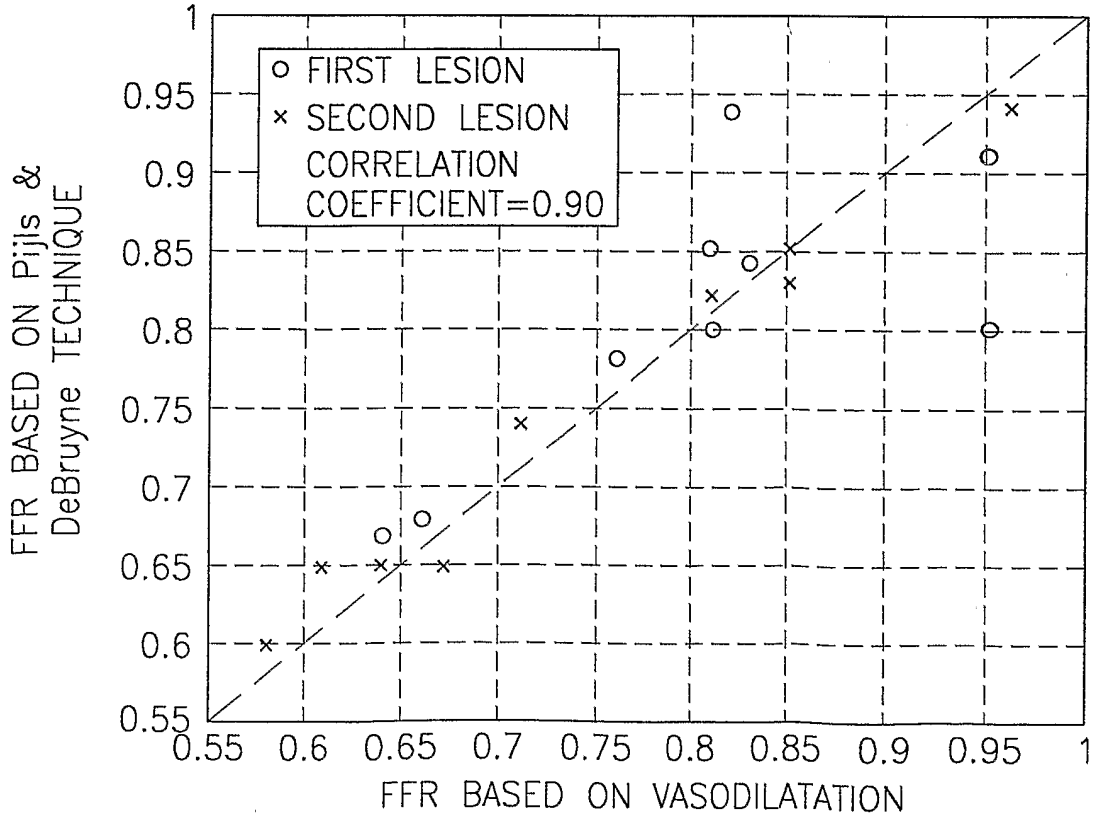
FIRST LESION
SECOND LESION
CORRELATION COEFFICIENT=0.90
FFR BASED ON Pijls & DeBruyne TECHNIQUE
FFR BASED ON VASODILATATION
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95 1

FIG.7