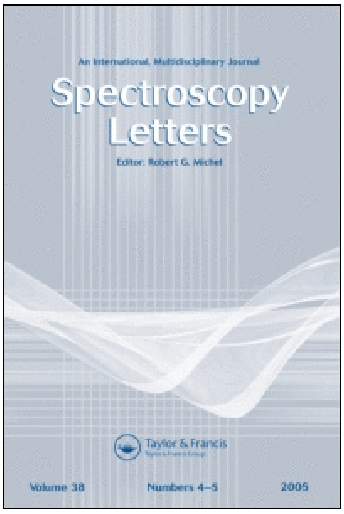

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Cine-MR Detection of Geometrical Size Anomalies in the Descending Chest Aorthic Artery for Some Heart Pathologies.

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CINE - MR DETECTION OF GEOMETRICAL SIZE ANOMALIES IN THE DESCENDING CHEST AORTHIC ARTERY FOR SOME HEART PATHOLOGIES.

KEY WORDS : Cine-MR, Chest aorthic artery aneurysm , Right atrial mixoma.

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ABSTRACT

In this MRI work the Fast Gradient - Echo technique has been applied to the detection of the geometrical and elastic properties of the chest aorthic descending artery to check probable troubles in the blood flux which subtend several heart pathologies. The average diameter and the time variations of the aorthic vessel have been measured in the axial scanning plane to minimize the experimental

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errors. From the analysis of the vessel average diameter and the related root mean square deviation, a parameter named Contractility has been defined , in close relation with the elastic properties of the aorthic vessel. This parameter measured in patients affected from heavy cardiac pathologies such as aorthic arc aneurysm and right atrial mixoma shows remarkable variations when compared to the values obtained in healthy subjects. The use of the Contractility is suggested for a quick MRI determination of these cardiocircolatory pathologies.

INTRODUCTION

Recently [1,2,3,4,5] the MRI tecnique has been applied, successfully, to the in vivo acquisition of well detailed images of the hearth region both in healthy and pathologic state.The experimental shortcomings to obtain the best possible MRI pictures with the maximum reduction of artifacts , due either to the in time hearth muscle constant pumping activity with the simultaneous drawback of the complicate hydrodynamics of the blood high rate flow and either to the breathing action of the patient under test , have been overcomed with the discovery of fast signal averaging tecniques which reduce the clinic test time from 17 to about 3 minutes [6,7,8]. In this way the psychological stress particularly intense in claustrophobic patients is severely reduced. In this preliminary work we have measured the average diameter of the chest descending aorthic artery in the arc section. The measures are complicated from the blood dynamics in uneven pulsed motion with appreciable deviation from the idealized state of the newtonian fluid in condition of laminar flux. In such a case we are intrigued from the presence of whirlwind motions with Reynolds number ≥ 3000 , as reported in literature , [9,10] which origin either in the pulse frequency variations of the cardiac muscle than in the lumen variations of the aorthic artery. The intensities of the MRI signals are considerably dependent from all these flow conditions , but allowing to the relatively large lumen of the aorthic artery compared to the all other blood vessels and using ultrafast tecniques in the collection of the experimental data , which practically cancel every artifact with origin in the body intentional and unintentional movements, we have been able to effect the measurements reported in this work assuming a quasi newtonian blood flux behaviour[10] . The experimental data reported here have been always obtained with the MRI instrument triggered from the voltage peak of the R wave response of a coupled ECG device , hence always on the same phase of the hearth cycle . We have thus studied the aorthic artery diameter and its time variations for an ensemble of subjects with an high degree of statistical variance such as the age , sex and different hearth pathologies comparing the results to a control group set up with healthy pazients of both sex with variable age. To do so , we have adopted the CINE-MR method well described in literature [4,5,6] . The results obtained in such a way with the definition of an elastic parameter, that we have called

Contractility, are encouraging mainly for the cases in which are present pathologies which change the elastic behaviour of the aorthic artery as described in the next sections of the work. In this study we have checked several hearth and aorthic artery diseases [6] such as benignant and malignant tumours, coronary strokes, angina pectoris and pericardities [7] , verifying variations in the Contractility which are negligible in the coronary strokes and the tumoral diseases but very important for the aorthic aneurysms and right atrial mixoma .

EXPERIMENTAL SECTION

Forty pazients, bedridden in the our hospital ,with diverse hearth pathologies have been the subject of the MRI session with an instrument Siemens at the static magnetic field of 1.5 T and equipped with a suitable cardio-coil. The instrument is coupled to an ECG device and the peak voltage of the hearth R wave triggers the start of the MRI pulses sequence with a time delay of about one second between successive scans.With the application of three field gradients directed properly along the cartesian axes, G_z slice width selection gradient G_y phase encoding gradient and G_x read gradient , we have been able to obtain spacial resolution of one millimeter voxel. As outlined in the introduction , with the aim to observe the aorthic artery geometry ,we have applied the most suitable slice scan tecnique i.e. the Gradient-Echo pulse sequence and its known implements [2,7,9] . The aorthic artery images have been collected by using the following parameters :

1) Repetition time TR for one image acquisition : 0.3 s.
2) Signal averaging number N_S : 4.
3) Acquisition matrix dimension Dim [m] : 165 × 256.

Hence the total acquisition time is :

$$\textbf{Total time} = \textbf{TR} \times \textbf{Ns} \times \textbf{Dim [m]} \qquad (1.1)$$

To further reduce the scan time we have used flip-angle in the interval between 30°- 60° as described in literature [8] together with the simultaneous perfusion of paramagnetic salt T_1 relaxation time relaxer as the Gd-DTPA : this protocol has been used for all the patients examined . In this way as can be calculated from the relationship (1.1) we have obtained total scan times of about three minutes . Pazients suffering different pathologies related to the hearth region have been the object of quantitative aorthic artery measurements . The number of data acquired has statistical relevance for some hearth damages while other are only informative . In general we have obtained 14 aorthic artery sections for any single patient in any session in order to follow the time variation of the artery diameter . Selected

patients have been resampled at random after an opportune time delay for a further statistical check on the measures . The aorthic artery cross section images appear with a fine contrast with neat boundary zone . By using a commercial Image Treatment program we have determined for every artery cross section the average diameter . A greater confidence has been derived by measuring the average artery diameter in cross sections shifted a bit up and down from the aorthic region selected . The difference is totally negligible resulting smaller than one millimeter .
All the experimental significative values are reported in the tables of the next section together with the values of a parameter , called by us , Contractility and defined as :

$$C = \frac{<\sigma>}{< d >} \qquad (1.2)$$

where $<\sigma>$ is the population average root mean square deviation for each representative measurement and $<d>$ is the corresponding aorthic average value . We also report the values of another parameter :

$$C_r = \frac{C_x - C_0}{C_0} \qquad (1.3)$$

which is related to the normalized relative deviation of the mean Contractility C_x of the pathologic aorthic artery compared to the healthy one C_0 , assumed as reference.

RESULTS AND DISCUSSION

In the Table 1 are reported the results of the our work on the chest descending aorthic artery diameters of the healthy control group ad obtained from the MRI Cine-MR.
Looking to this table we observe the nearly invariance with the sex and the age of this one and all the related parameters σ and C whose average values are tabulated in the third row of the Table 2 . It derives that the healthy state of the hearth does not cause any strain to the aorthic artery geometry and these results describe the appropriate artery behaviour. In the Table 2 the overall population averages are reported for the same artery in different hearth pathologies. In the same table the experimental values of the absolute and relative aorthic Contractilities are given.

TABLE 1

Characteristic Contractilities C for healthy patients.

	Diagnosis	d (mm)	σ (mm)	C
Pat. n. 1 M. Age 16 Resampled	Healthy	19.64 19.99 20.86	0.90 1.24 1.16	0.05 0.06 0.06
Pat. n. 4 M. Age 48	"	22.38	0.95	0.04
Pat. n. 5 M. Age 28	"	20.41	0.82	0.04
Pat. 10 W. Age 50 Resampled	"	20.72 20.29 20.37	1.10 1.15 0.98	0.05 0.06 0.05
Pat. n. 25 M. Age 19 Resampled	"	21.58 21.01 20.70	0.96 1.12 1.21	0.04 0.05 0.06
Pat. n. 29 m. Age 44	"	22.99	1.90	0.09
Pat. 40 W. Age 36	"	22.99	1.90	0.09
Pat. 3 m. Age 55	"	20.31	1.96	0.10

We emphasize the fact that for each pathology studied the number of the cases sampled varies between one and sixteen . The single case are without statistical significance and are quoted only for the sake of information . The other items , i.e. the samples tagged healthy , coronary , right atrial mixoma and particularly the aorthic arc aneurysm are collected over a sufficient samples number to retain a degree of statistical validity . As a matter of fact , for the healthy patients control group we observe the lowest magnitudes for all the relevant parameters $<d>$, $<\sigma>$, C and C_R . In all other hearth pathologies the measured parameters vary slightly with respect to that obtained for the control group wirh the only exception in the case of patient affected from angina which show really a three millimeter decrease in the aorthic artery diameter . On the contrary great variation are found for the timoma tumoral form, neverthless present in only one case and for the right atrial mixoma in a relatively sufficient number of cases . In

TABLE 2

MRI values of the average diameter of the chest descending aorthic artery <**d**>, root mean square deviation <σ>, Contractility **C** and deviation C_r in several pathologies of the cardiac region .

Samples Number	Diagnosis	< d > (mm)	< σ > (mm)	C	C_r
1	Angina	17.29	2.38	0.138	1.51
1	Stenosis	20.06	1.14	0.057	0.4
8	Healthy	20.91	1.14	0.055	0.00
1	Bypass	20.91	2.62	0.125	1.27
3	Restricted pericar.	22.34	1.53	0.07	0.3
2	Sarcoma	24.31	1.20	0.05	-0.10
2	Right Ventr. Miocard.	25.10	1.31	0.05	-0.10
1	Timoma	30.00	2.4	0.08	0.46
6	Right Atrial Mixoma	30..55	2.65	0.152	1.77
16	Aorthic Arc Aneurysm	32.63	7.50	0.202	2.67
8	Coronary	22.98	1.70	0.07	0.3

this work the most high variations of all the parameters are found for the case of aorthic artery aneurysm . The Table 3 reveals for sixteen patients the details of the aorthic artery behaviour in this disease. The aneurysm struck patients show artery diameters which span the interval with boundaries included between 21 and 45 millimeters together with remarkable values of σ . The dramatic case of σ equal to 27.3 millimeters in the same table at the row 5 belongs to a patient died few days after the MRI check . The values of the artery contractility C vary between a lower limit of 0.04 practically equal to that in the healthy control group and the upper limit of 0.24 which is about fivefold greater than the average value reported in the Table 2 for the control group . Moreover the root mean square deviation σ reaches the maximum peak at 9.54 eight times greater than that in the healthy control group. In the Figure 1 the time response of the aorthic artery diameter for some selected hearth pathologies is plotted against the successive slice number i.e the elapsed time between different measures .The plot for the healthy patients is a straight line while that for patients affected from right atrial mixoma and aorthic arc aneurysm show an oscillating trend much more enhanced for the last disease. The time average values for the two hearth damages of respectively 30.34 $\pm$5.32 mm and 45.1$\pm$9.2 mm are statistically significant with respect to the control group value of 19.6$\pm$1.7 mm. On the base of these experimental findings we have discovered that there is an approximate linear relationship between $<\sigma>$ and $<d>$:

$$<\sigma> = -6.43 + 0.343 <d> \qquad (1.4)$$

with the correlation coefficient R = 0.77. This linear behaviour is foreseen in the the flow dynamics for what concerns the motion of a fluid in a deformable pipe [10] .

This linear relation is derived with the exclusion of the anomalous cases of the angina and of the dubious cases of bypass operated patient .

On the base of these experiments we can suggest to the medical community that the MRI determination of the arterial diameter , hence the contractility index , can be one useful way easy to perform and not too much time consuming in the diagnosis of some arterial pathologies, specially for that which force heavy burden to the blood flow in the circulation network.

In the future we think to extend this MRI method to collect further informations on the greater hearth vessels and on the other different big blood flow pipes in the human body specially in what concerns the arteries which feed the brain.

CONCLUSIONS

All the previous considerations suggest a check protocol suitable to every hearth medical center equipped with the required MRI instruments .

In this way it is possible to study anomalies of the blood flow in strained arteries

TABLE 3

Characteristic Contractilities C for patients affected from aneurysm of aorthic artery.

	Diagnosis	d (mm)	σ (mm)	C
Pat. n. 2 M. Age 66	Aorthic Arc Aneurysm	21.61	1.95	0.09
Pat. n. 9 W. Age 76 Resampled	"	27.81 27.46 28.39	0.99 1.28 2.78	0.04 0.05 0.10
Pat. n. 12 W Age 36	"	28.68	6.44	0..2
Pat. n. 13 W. Age 51	"	32.49	3.58	0.11
Pat. n. 15 W. Age 74	"	47.71	27.29	0.57
Pat. n. 16 W. Age 74	"	32.59	5.03	0.15
Pat. n. 18 M. Age 49	"	44.35	8.20	0.18
Pat. n. 33 W. Age 73	"	44.85	8.20	0.19
Pat. n.34 M. Age 60	"	28.29	5.67	0.20
Pat. n. 35 M. Age 40	"	45.04	9.54	0.24
Pat. n. 36 M. Age 55	"	39.72	9.38	0.24
Pat. n. 37 M. Age 57	"	35.8	6.44	0.19

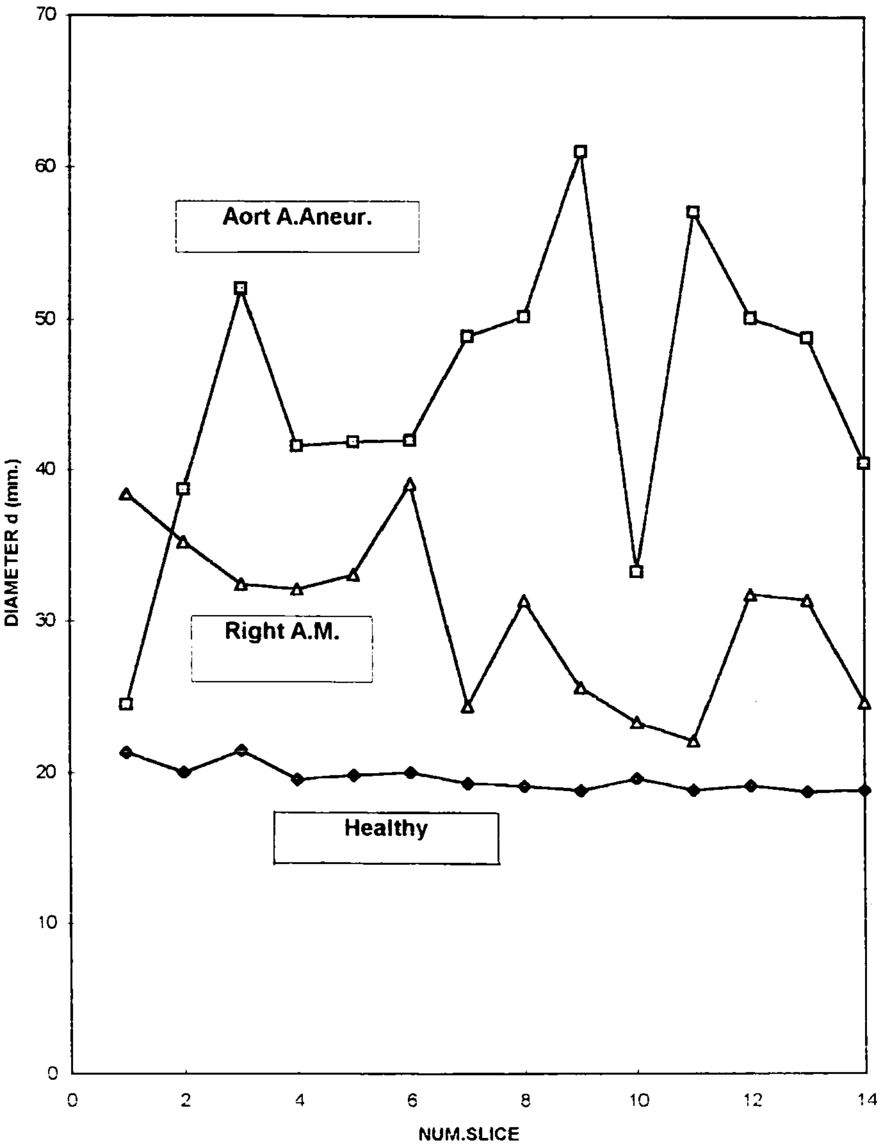

FIGURE 1.
Time behaviour of the aorthic artery diameter for three heart region pathologies.

with the use of a fast MRI tecnique such as the Cine-MR , measuring in few minutes important artery parameters, as we have done for the aorthic artery diameter in selected regions, deriving thus the artery Contractility for a quick information on the overall artery state and it eventual troubles.
For this kind of check we recommend to couple always the MRI session with the ECG response to establish the images time scale when the patient is monitored for relatively long time in order to establish the artery dynamical behaviour.

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