

## QUANTITATIVE ANGIOGRAPHIC ANALYSIS OF RIGHT VENTRICULAR GLOBAL FUNCTION IN NORMAL INCIDENCES AND IN PATIENTS WITH ONE-VESSEL CORONARY ARTERY DISEASE

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Sağ ventrikül volüm ve fonksiyonların yazılımla kantitatif analizinden önceki çalışmalarda sağ ventrikülografi verileri doğru olarak hesaplanamamaktaydı. Çalışmamızda sol ventrikül analiz yazılımı kullanarak sağ ventrikül volüm ve fonksiyonlarının koroner lezyonu olmayan ve tek damar koroner lezyonu olan hastalarda karşılaştırdık otuz sekiz koroner arterlerinde lezyon olmayan ve 27 tek damar koroner arter hastalığı olan hastada sol ventrikülografi ve sağ atriografi yapıldı. Her iki görüntüleme 2 projeksiyonda alındı. 30 sağ anterior oblik (RAO 30) ve 60 sol anterior oblik (LAO 60) projeksiyonlar. Sol ve sağ ventriküller strok volümlerin oranı kullanılarak

düzeltilme faktörü (CF) hesaplandı. Ortalama CF koroner arter hastalığı olmayanlarda  $0.924 \pm 0.289$  ve tek damar koroner arter hastalarında  $0.876 \pm 0.223$  tespit edildi. Bu metotla, yazılım kullanılarak, kantitatif anjiyografik analiz yardımı ile sağ ventrikül volüm ve fonksiyonları hesaplanabilmektedir.

**Anahtar kelimeler:** Kantitatif anjiyografi, Sağ ventrikül, Strok volüm, Düzeltme faktörü, Koroner arter hastalığı, Girişimsel kardiyoloji

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### INTRODUCTION

Methods of selective angiography were first developed in late 1950s by M.Sones and R.Favaloro<sup>1,2,3,4</sup>. When methods of quantitative angiographic analysis were implemented, invasive diagnostics grew much more informative<sup>5,6</sup>. However, the quantitative analysis (QA) was mainly developed for the left ventricle (LV), whereas right ventriculography was largely evaluated on the visual basis. It was partly connected to the fact that LV is shaped as an ellipsoid, which permits easy calculation (Dodge area-length method, Simpson's rule), while RV's geometrical shape impedes QA of its function and volumes<sup>7</sup>. Stereometrical model of RV is a pyramid with a triangle base. Such a model, however, does not allow for the transversal widening of RV and for the area in before the tricuspid valve.

Over a number of years several methods of measuring correct RV volumes on the basis of X-ray angiography had been proposed<sup>5-7,9</sup>. The model sug-

gested by J.Ferlinz proved to be the most accurate<sup>11,12</sup>.

Unfortunately, QA software only utilize Simpson's rule and Dodge area-length method for LV volumes and function estimation<sup>7</sup>. Like in past study<sup>8</sup> it was decided to calculate right ventricular function using Simpson's rule for LV provided in quantitative analysis software. More accurate volumes were obtained after the correction factor (CF) had been calculated through LV and RV stroke volumes (SV) ratio.

### METHODS

**Patients selection criteria:** Sixty-five patients with typical chest pain hospitalized in 2000-2004 were studied. The patients were divided into two groups according to the results of coronary angiography. The first group was formed of twenty-seven patients with one-vessel CAD who had hemodynamically significant lesion of one coronary artery (over 50% of the diameter). The other (normal) group included thirty-eight patients without significant lesions of coronary arteries. All patients studied were made aware of the invasive examination and gave their informed written consent.

### DIAGNOSTICS

Noninvasive testing included electrocardiography, echocardiography. Patients with LV aneurism, signifi-

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**Table 1:** Baseline characteristics

Variance	CAD group	Normal group	P
Age, years	53.0±7.2	46.1±10.8	NS
Sex, % woman	14.8	18.4	NS
Height, sm.	168.3±6.4	169.4±7.3	NS
Weight, kg.	72.3±7.5	74.1±10.4	NS

NS - not significant

**Table 2:** Quantitative analysis of angiograms

Variance	One-vessel CAD group	Normal group	P
Heart Rate, b.p.m.	87.0±14.0	94.8±21.7	NS
<b>Left Ventriculography</b>			
LV EDV, ml.	78.5±18.5	55.8±14.7	0.0033
LV ESV, ml.	26.3±3.6	14.1±5.5	0.00002
LV SV, ml.	52.2±17.5	41.7±10.9	NS
LV EF, %	65.2±8.0	75.0±6.1	0.0028
<b>Right Atriography</b>			
LV Physiol. EDV, ml.	79.6±22.3	60.1±22.8	0.0246
LV Physiol. ESV, ml.	28.5±10.3	13.7±5.7	0.00009
LV Physiol. SV, ml.	51.2±14.8	46.5±12.6	NS
LV Physiol. EF, %	64.4±6.5	76.6±4.9	0.000011
RV EDV, ml.	96.2±22.3	74.6±24.2	NS
RV ESV, ml.	36.1±11.4	21.5±9.0	0.0022
RV SV, ml.	60.1±17.2	53.2±18.0	NS
RV EF, %	62.4±9.7	71.3±6.2	0.0105

cant hypertrophy of LV, left bundle branch block, other arrhythmias and valve disease were excluded from further examination.

Invasive diagnostics was performed on a digital angiographic complex Coroscop 33 Plus (Siemens, Germany). Prior to the examination routine premedication of all patients with diazepam and chloropiramine was performed. All patients underwent X-ray coronary angiography, LV angiography and right atrium (RA) angiography with injection of contrast media into RA and its successive passage through RV, left atrium and LV. We used non-ionic contrast media iohexol only.

LV and RA angiography was carried out in two orthogonal projections RAO 30 and LAO 60. The contrast media injection rate was 12 to 18 ml/sec for LV and 10 to 14 ml/sec for RA.

Quantitative angiographic analysis was performed with QuantCor LVA software (Siemens, Germany).

Coronary artery lesions were calculated in the Quantitative Coronary Arteriography module. The criterion of a lesion's hemodynamic significance was its binary level over 50% of the artery diameter or over 75% of the area according to morphological and den-

sitometric data.

Quantitative analysis of the left and right ventricles were performed in Left Ventricular Analysis module. The ventricle outline was traced semi-automatically with manual correction in case of considerable software fault. Initial variables were calculated using Simpson's rule.

Mathematical model of right ventriculography and statistical analysis.

It is well-known that left ventricular volumes obtained during LV contrasting differ from physiological ones<sup>13</sup>. The reason is extra pressure in the left ventricle resulting from considerable amount of contrast media, which often leads to arrhythmias, such as extrasystole and tachiarhythmias runs.

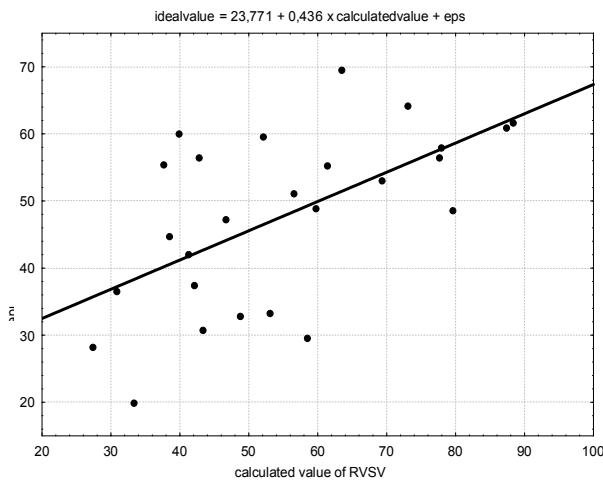
To obtain physiological data on LV function a method of right atriography when contrast media passes through the right atrium, right ventricle and lungs and gets into the left atrium and left ventricle was suggested<sup>13</sup>. This method prevents excessive pressure on left ventricular walls as well as arrhythmias.

Injecting contrast media into the right atrium makes it possible to get images not only of the left but also of the right ventricle. Since contrast media does

**Table 3:** Estimation of right ventricular global function

Variance	One-vessel CAD group	Normal group	P
CF (correction factor)	0.879±0.223 (0.506/1.161)	0.924±0.289 (0.599/1.508)	NS
RV EDV with CF, ml.	82.1±19.9	65.7±19.5	NS
RV ESV with CF, ml.	30.9±12.0	19.2±9.2	0.0142
RV SV with CF, ml. (eq. LV Physiol. SV)	51.2±14.8	46.5±12.6	NS
RV EF, %	62.4±9.7	71.3±6.2	0.0105

**Figure 1:** Regression model of RSV ideal value (eq. LV Physiol. SV) on RSV calculated value



not distend the right ventricle, its volumes can be considered physiological.

Deliberately inaccurate quantitative analysis of the right ventriculogram using Simpson's rule was carried out during quantitative analysis of left ventriculography based on digital images recorded after right angiography. Non-indexed volumes were used in the calculations. After physiological data on the LV were obtained from right atriography, ratio of LVSV to RSV was found using correction factor. This calculation was done separately for each patient from both groups, then mean CF was found for patients without CAD (normal) and for patients with one-vessel CAD.

After that, each patient's RV volumes were recalculated by multiplying them by the group's mean CF. Data per group were compared using Student's t-test, Chi-square criterion or Fisher exact test.

Finally, regression analysis was performed, comparing SV deviations appearing when Simpson's rule is utilized for RV.

The data are presented like mean standard de-

viation (SD). Significant level was considered  $p < 0.05$ . Software package "Statistica for Windows Release 5.5A" (StatSoft Inc.) was used for the analysis.

## RESULTS

No significant differences between the groups were revealed after patients had been compared on the basis of sex, age, height and weight. Mean data and SD are presented in Table 1. Quantitative analysis of left ventriculography showed that LV volumes and ejection fraction were different in the two groups (Table 2). At the same time, SV did not have significant inter-group differences. Right atriography revealed similar differences in LV volumes and function. RV quantitative analysis showed differences only between the groups' end systolic volume (ESV) and ejection fraction (EF) (Table 2).

When RSV was recalculated with physiological LVSV, correction factor was found, Table 3 (mean, SD and range). Thus RSV became equivalent to LVSV, RV volumes changed. CF did not have significant intergroup differences. To calculate EF, SV is divided by end diastolic volume (EDV). CF in the fraction's numerator and denominator gave 1 when divided, hence RVEF did not change when CF was applied to volume data.

A linear regression model (Figure 1) was used to find correlation of calculated value of RSV to the most accurate (ideal) value of RSV, equivalent to LVSV. The following equation (Eq. 1) was developed:  $idealvalue = 23.771 + 0.436 \times calculatedvalue$  (Eq. 1)

## DISCUSSION

As previous research results have demonstrated, the most accurate estimation of right ventricular volumes and function can be performed with J.Ferlinz Formula<sup>6,10,11,12</sup>. The author continued his research and tried to simplify the model by introducing RV single plane calculations instead of biplane<sup>11</sup>.

Calculations utilizing Dodge area-length method

for RV did not reduce calculations and demanded regression analysis<sup>5</sup>. Standard deviation was over 10% with any model, totalling 28% with least exact RV volume calculations<sup>5</sup>.

An attempt to find ratio of indexed LV and RV volumes using Dodge method with the subsequent original model of regression analysis by Wynne resulted in the following ratio (Eq. 2):

$$\text{True volume} = 0.789 \times \text{calculated volume} + 0.3 \quad (\text{Eq. 2})$$

and revealed differences between LV and RV diastolic and systolic volumes<sup>6</sup>. Consequently, EF of LV and RV was also different. In 19 patients there was no significant difference between LVSV and RVSV. This SV equivalence is 1 of fundamental hemodynamic laws, which was applied later in our study.

Semielliptical model for RV was estimated in seven patients due to the absence of software for RV analysis<sup>7</sup>. Correlation coefficient  $r=0.96$  between the calculated RV volume and true RV volume was obtained.

An attempt to utilize Simpson's rule for RV was undertaken with thirty-eight patients<sup>9</sup>. When routine angiograms were compared to autopsy results, correlation coefficient  $r=0.99$  was obtained and correction factor (0.749) was found to calculate true RV volume on the basis of the calculated volume.

Our research on RV function estimation conducted for a number of years first in Russia and then in Turkey<sup>14-16</sup> made it possible to assess the complexity of RV analysis by J.Ferlinz and to suggest several original algorithms<sup>14</sup>.

The present study became possible after the introduction of quantitative analysis software for LV with Dodge area-length and Simpson's algorithms. Despite supposed relative accuracy of the data, the research provided RV volumes close to the true ones. There were no significant differences in correction factor between patients with one-vessel CAD and without CAD, although CF was smaller in patients with one-vessel CAD. Since indexation of RV volumes is finding their ratio to the body surface area (BSA), indexation in groups was not conducted not to distort CF. This calculation per BSA should be performed in each patient after CF has been applied to the variables.

Another important research fact is that the ventriculographic analysis was conducted with physiological volumes and function. The majority of previous researchers did not specify whether extrasystole was recorded and whether contractility was normal.

Study limitations: The study only used basic software algorithms for LV analysis in order to create the easiest recalculation method for RV. Similar recalculation models can probably be obtained for other software packages.

## CONCLUSION

This method can be used for calculation of volume and function RV by using existing software of quantitative angiographic analysis. The difference in correction factor between patients without CAD and patients with one-vessel CAD allows to differentiate estimation of RV data.

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