Estudi de la regeneració miocàrdica en la miocardiopatia alcohòlica i la seva relació amb el dany funcional i estructural miocàrdic, activació d'apoptosi i activitat miostatina

Meritxell Lluís Padierna

ADVERTIMENT. La consulta d'aquesta tesi queda condicionada a l'acceptació de les següents condicions d'ús: La difusió d'aquesta tesi per mitjà del servei TDX (**www.tdx.cat**) ha estat autoritzada pels titulars dels drets de propietat intel·lectual únicament per a usos privats emmarcats en activitats d'investigació i docència. No s'autoritza la seva reproducció amb finalitats de lucre ni la seva difusió i posada a disposició des d'un lloc aliè al servei TDX. No s'autoritza la presentació del seu contingut en una finestra o marc aliè a TDX (framing). Aquesta reserva de drets afecta tant al resum de presentació de la tesi com als seus continguts. En la utilització o cita de parts de la tesi és obligat indicar el nom de la persona autora.

ADVERTENCIA. La consulta de esta tesis queda condicionada a la aceptación de las siguientes condiciones de uso: La difusión de esta tesis por medio del servicio TDR (**www.tdx.cat**) ha sido autorizada por los titulares de los derechos de propiedad intelectual únicamente para usos privados enmarcados en actividades de investigación y docencia. No se autoriza su reproducción con finalidades de lucro ni su difusión y puesta a disposición desde un sitio ajeno al servicio TDR. No se autoriza la presentación de su contenido en una ventana o marco ajeno a TDR (framing). Esta reserva de derechos afecta tanto al resumen de presentación de la tesis como a sus contenidos. En la utilización o cita de partes de la tesis es obligado indicar el nombre de la persona autora.

WARNING. On having consulted this thesis you're accepting the following use conditions: Spreading this thesis by the TDX (**www.tdx.cat**) service has been authorized by the titular of the intellectual property rights only for private uses placed in investigation and teaching activities. Reproduction with lucrative aims is not authorized neither its spreading and availability from a site foreign to the TDX service. Introducing its content in a window or frame foreign to the TDX service is not authorized (framing). This rights affect to the presentation summary of the thesis as well as to its contents. In the using or citation of parts of the thesis it's obliged to indicate the name of the author.

OXFORD JOURNALS

ALCOHOL AND ALCOHOLISM

EVALUATION OF MYOCYTE PROLIFERATION IN ALCOHOLIC CARDIOMYOPATHY. TELOMERASE ENZYME ACTIVITY (TERT) COMPARED TO Ki-67 EXPRESSION.

Journal:	*Alcohol and Alcoholism*
Manuscript ID:	Draft
Manuscript Type:	Original Manuscript
Date Submitted by the Author:	n/a

Complete List of Authors:	LLUIS PADIERNA, MERITXELL; HOSPITAL CLINIC, ALCOHOL RESEARCH UNIT FERNANDEZ-SOLA, JOAQUIM; ALCOHOL UNIT, MEDICINE CASTELLVI, SERGI; IDIPABS, DEPARTMENT OF MEDICINE. UNIVERSITY OF BARCELONA SACANELLA, EMILIO; HOSPITAL CLINIC, ALCOHOL RESEARCH UNIT ESTRUCH, RAMON; HOSPITAL CLINIC, ALCOHOL RESEARCH UNIT URBANO-MARQUEZ, ALVARO; HOSPITAL CLINIC, ALCOHOL RESEARCH UNIT

Keywords:	alcohol cardiomyopathy, myocyte proliferation, TERT, ki-67

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

EVALUATION OF MYOCYTE PROLIFERATION IN ALCOHOLIC CARDIOMYOPATHY. TELOMERASE ENZYME ACTIVITY (TERT) COMPARED TO Ki-67 EXPRESSION.

RUNNING HEAD:

MYOCYTE PROLIFERATION in ALCOHOL CARDIOMYOPATHY

Meritxell Lluís M.D., Ph.D.[1]; Joaquim Fernández-Solà M.D., Ph.D[1,2]; Sergi Castellví Ph.D.[3]; Emilio Sacanella M.D., Ph.D[1,2]; Ramón Estruch M.D.,Ph.D.[1,2], Alvaro Urbano-Márquez[1]

[1]Alcohol Research Unit. Hospital Clínic. Institut d'Investigació August Pi i Sunyer (IDIBAPS). Department of Medicine University of Barcelona. Spain

[2]CIBEROBN Fisiopatologia de la Obesidad y la Nutrición. Instituto de Salud Carlos III, Spain.

[3]Gastroenterology Department, Institut de Malalties Digestives i Metabòliques, Hospital Clínic, CIBEREHD, IDIBAPS, University of Barcelona, Barcelona, Catalonia, Spain.

Department of Medicine. University of Barcelona. Catalonia. Spain.

For Peer Review

ABSTRACT: 259 words

TEXT: 4,396 words

TABLES: 2

FIGURES: 2

Submit correspondence to:

Joaquim Fernandez-Solà M.D.

Department of Internal Medicine. Alcohol Unit

Villarroel 170. 08036. BARCELONA- España

Phone and FAX: 00.34.93. 2279365

E-mail:jfernand@clinic.ub.es

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60

ABSTRACT

Aims: Although human heart was classically considered a terminal organ, recent studies have reported a myocyte proliferation response versus some aggressions. Excessive ethanol consumption induces development of cardiomyopathy (CMP) through myocyte apoptosis. We evaluated myocyte proliferation response in the heart of chronic alcoholic donors with telomerase activity (TERT) compared to Ki-67 nuclear expression.

Methods: Heart samples were prospectively obtained from organ donors on life support. We included donors wit 1) High lifetime alcohol consumption (n=15), 2)Longstanding hypertension (n=14), 3) Other causes of CMP (valve, coronary or idiopathic) (n=8), and 4) Previously healthy donors (n=6). Groups 2 and 3 were subdivided according to the presence of CMP. Evaluation comprised parameters of ethanol consumption, left ventricular (LV) function by chest X ray and 2-D echocardiography and histology and immunohistochemical studies. Myocyte proliferation was evaluated using an assay for Ki67 expression and measuring telomerase gene activity by real-time PCR.

Results: Fourty–three donors were included in the study, 35 having CMP. Nuclear Ki-67 activity was low in healthy controls and significantly increased in the other groups, mainly in those with CMP. Alcoholics with CMP had a non-significantly lower proliferation response than the other CMP groups. No proliferation activity was detected with TERT in any case.

Conclusions: Heart Ki-67 proliferation activity increases in organ donors with CMP, independently of its origin. Alcoholics presented non-significant lower myocyte proliferation capacity compared to the other groups of CMP. TERT activity was not a useful marker of proliferation in this model. Ki-67 is a better procedure to evaluate proliferation than TERT expression in alcohol–induced heart damage.

For Peer Review

Key words: Alcohol, Cardiomyopathy, Telomerase, TERT, Ki-67.

INTRODUCTION

Recent scientific knowledge has shown that the human heart is not a terminal organ (Anversa and Kajstura,1998; Nadal-Ginard et al, 2003a; Quaini et al, 2004; Buja and Vela 2008). Heart exhibits plastic response versus diverse physiologic or pathologic stimuli (Hill and Olsen, 2008; Kajstura et al, 2004; Gerder, 2002). Cardiac myocyte renewal has been observed in different animal species (Soonpaa and Field, 1998; Jopling, 2010), and also in human myocardial areas surrounding necrotic tissue (Beltrami et al, 2001; Urbanek et al, 2005). Therefore, a relationship between myocyte necrosis and subsequent proliferative response has been established (Anversa and Nadal-Ginard, 2002; Beltrami et al, 2003; Anversa et al, 2004).

In last decades, a dose-dependent relationship between excessive alcohol consumption and diffuse myocardial damage has been corroborated (Urbano-Márquez et al, 1998; Molina et al, 2002; Piano, 2002; Nicolás et al, 2002; Urbano-Márquez and Fernández-Solà, 2004). Mechanisms underlying this effect are diverse, with direct induction of apoptosis and myocyte cell death by ethanol (Jänkalä et al, 2002; Molina et al, 2002; Fernández-Solà et al, 2006). However, not all excessive alcohol consumers develop significant myocardial damage, with some discordance between the high prevalence of alcohol consumption and the relative low incidence of alcoholic CMP (Fernández-Solà et al 2002; Urbano-Márquez et al, 1995). It has been suggested that some mechanisms may compensate the degree of alcohol-induced myocyte damage (Urbano-Márquez and Fernandez-Solà, 2004).

We previously analyzed factors influencing death and proliferation of cardiac myocytes and observed a higher apoptosis index and myostatin activity in alcoholic compared to

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

healthy donors (Fernández-Solà et al, 2006). Alcoholics with CMP showed higher apoptotic and proliferative Ki-67 activity compared to their partners without CMP. Chronic ethanol consumption increases myostatin activity, a factor that favors loss of cardiac myocytes and impairs their proliferation (Fernández-Solà et al, 2008).

Several morphological, immunohistochemical and molecular markers have been used to evaluate myocyte proliferation (Leri et al, 2001). Ki67 is a nuclear antigen only expressed when cells are in the replication cycle. It is commonly used as a marker of cell proliferation either in tumoral (Magdelénat, 1992) or non-tumoral tissues including cardiac myocytes (Kajstura et al, 1998; Nadal-Ginard et al, 2003b; Anversa and Nadal-Ginard, 2002). Telomerase is a DNA polymerase constituted by two RNA subunits (telomerase-RT) (TERT) that maintains the telomere length stable and protects chromosomes from degradation and molecular recombination. When telomerase activity decreases, telomere length shortens to a critical size, activates cell apoptosis and stimulates TERT expression as a compensatory mechanism. This process physiologically appears along senescence (Anversa et al, 2005), being implicated in ischemia (Serrano and Andres, 2004), heart failure (Leri et al, 2003), ventricular hypertrophy (Urbanek et al, 2003), infertility and sarcopenia (Blasco, 2005). In contrast, telomerase exhibits a high activity in progenitor stem cells (Djojosubroto et al, 2003) and in tumoral cells, (Blasco, 2005).

All these facts led us to consider the possible increase in telomerase activity and proliferation response in the setting of alcoholic CMP. This myocyte proliferation would partially compensate the ethanol-induced myocyte loss (Nadal-Ginard et al, 2003a; Hotchkiss, 2009). Differences in the myocyte proliferation response may explain discordances in the relation between ethanol intake and the degree of cardiac lesion.

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

In the present study we evaluated proliferation mechanisms similar to those described in ischemic CMP in the heart of chronic alcoholics. In a prospective case-control study using heart samples from human donors we assessed the effect of alcohol consumption on myocyte proliferation, evaluated by cardiac myocyte telomerase activity and expression of Ki67 nuclear antigen.

MATERIALS AND METHODS

Patient selection

Over a two-year period (September 2006 to November 2008), we consecutively studied hearts from subjects who had brain death either of traumatic or cerebrovascular origin, and had been considered suitable as organ donors by the transplant team of the Hospital Clínic of Barcelona.

Of 127 cadaveric donors younger than 70 years of age, 43 hearts were not suitable for transplantation. Of these latter organs, we selected 14 with chronic hypertension, 15 cases with a history of ethanol intake (≥ 60 g/day, longer than 10 years) and 10 hearts from healthy people who were not eligible for implantation because of a lack of matched receptor or size inadequacy. Additionally, 8 specimens from patients with heart disease (three coronary diseases, three with idiopathic dilated CMP and two with valve-heart disease) were selected. Alcoholic and hypertensive donors were subdivided in two groups depending on the existence or not of CMP.

Exclusion criteria: According to the general protocol of organ donation, subjects with drug misuse, transmissible infections (HIV, hepatitis B or C), sepsis, disseminated neoplasm or metabolic diseases (diabetes or other endocrine diseases) or other diffuse structural diseases were excluded as were those with coexistent hypertension and alcohol consumption.

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

All patients were white Caucasians of Spanish descent, who lived with their families in or around Barcelona and none was indigent. The study protocol was approved by the Ethics Committee of the Hospital Clinic and included informed consent from the families of the donors concerning the use of myocardium tissue for this research protocol study. One third of these subjects had been included in previous studies on cardiac apoptosis and (Fernández-Solà et al, 2006) and myostatin activity (Fernández-Solà et al, 2010).

For Peer Review

All cases had been admitted to the Intensive Care Unit, and ventilatory and hemodynamic parameters were appropriately maintained at normal values throughout hospitalization: P_aO_2 greater than 60 mmHg, systolic blood pressure greater than 100 mmHg, and arterial pH within the normal range. None of the patients required in-hospital cardiopulmonary resuscitation maneuvers.

Clinical and laboratory evaluation

Detailed history of ethanol intake was retrospectively obtained by consultation with family members using a structured questionnaire ("time-line follow-back method") (Sobel et al, 1979) as previously reported (Urbano-Márquez et al, 1989; Nicolas et al, 2002). Duration of ethanol intake was calculated in each group as the total cumulated period of alcohol consumption in years, either recent or previous. Body mass index was determined as the actual body weight relative to the square of the body height (BMI, Kg/m^2). Patients were considered to have caloric malnutrition if the BMI was less than 17 Kg/m^2.

Cardiac Studies

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Past and present signs and symptoms of heart failure were evaluated in consultation with medical records and family members of the donors, and the New York Heart Association (NYHA) functional class was determined according to the Goldman activity scale (Goldman et al, 1981). Chest X-ray with measurement of cardiothoracic index and conventional electrocardiography were performed in all cases. Moreover, a bi-dimensional echocardiography was performed (Hewlet Packard Sonos 2500, USA) in 14 patients compared to none of the controls with a cardiothoracic index greater than or equal to 0.48. End-diastolic and end-systolic diameters, the shortening fraction, the left ventricular mass, and ejection fraction were measured according to the standards of the American Society of Echocardiography (Gottdiemer et al, 2004). Cardiomyopathy was defined in the presence of a LV ejection fraction < 50% and LV dilatation. We observed a good correlation between the cardiothoracic index and the left-ventricle end-diastolic diameter ($r = 0.68$, $p < 0.01$). The personnel who performed and evaluated these tests had no knowledge of the alcoholic history of the patients.

For Peer Review

Myocardium histological studies

A distal 3 cm sample of the left-ventricle apex was surgically excised (total weight of 4-5 g) at the time the donor was under cold perfusion. The specimen was cut into fragments, and one of these was processed for further histological analysis. The remaining fragments were immediately frozen (-80ºC) under liquid nitrogen until telomerase and Ki-67 studies were performed. Specimens were stained with hematoxilin-eosin and toluidine-blue in semi-thin sections for histological studies. Two independent observers (JF-S and AU-M) evaluated the degree of myocardial cell and nuclear hypertrophy, myocytolysis (defined as the presence of myofiber disarray, or cell vaquolization) and interstitial fibrosis. In case of discordance a consensus agreement was established. The amounts of interstitial fibrosis (volume fraction of fibrosis) and

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

cardiac muscle cells (volume fraction of the myocytes) were assessed as previously reported (Fernández-Solà et al, 1994). The degree of global histology involvement was graded as normal, mild, moderate, or severe according to previously defined histological criteria (Fernández-Solà et al, 1994; 1997 and 2002).

Myocardium proliferation studies

TERT Protocol

a) RNA extraction: The RNAqueous-4PCR kit (Ambion, Austin, TX, USA) was used to extract RNA from small size tissue samples (0.5-75 mg). From each cryopreserved sample, a fragment of 5 mg was obtained and RNA was isolated following the manufacturers' instructions. Finally, in order to eliminate trace amounts of DNA, a DNAse 1 and DNAse inactivation treatment was performed. RNA samples obtained were preserved at -80ºC. RNA quantity in each sample should be around 1-10 µg per mg of tissue. Since we considered a minimum of 50 ng/µl adequate, 10 of 53 samples were rejected, remaining 43 valid samples to study. Adequate RNA integrity and concentration was corroborated using the 2100 Bioanalyzer (Agilent, Santa Clara, CA, USA)

b) Retrotranscription from RNA to cDNA:

The High Capacity cDNA kit (Applied Biosystems, Foster City, CA, USA) was used to obtain cDNA from each sample using 1 µg of RNA according to the manufacturers' instructions. with a minor modification, the addition of RNAse Inhibitor (Applied Biosystems, Foster City, CA, USA) at a final concentration of 0.4 U/µl. Samples were incubated at 25ºC for 10 min and 37ºC for 120 min.

c) TERT expression quantification by real-time PCR:

The expression level of TERT was measured by real-time quantitative PCR using the TaqMan technology on a 7300 Real-Time PCR System (Applied Biosystems, Foster

For Peer Review

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60

City, CA, USA). Primers and FAM dye-MGB probe were developed by the manufacturer as a TaqMan Gene Expression Assay bridging exons 11 and 12 of the *TERT* mRNA sequence (NM_198253.2). TBP expression was monitored as the endogenous control gene in a duplicate of the same samples, being the assay available from the manufacturer as a VIC dye-MGB probe.

PCR reactions were prepared using 5 µl of cDNA in a final volume of 25 µl with final concentrations of 1 X TaqMan Gene Expression Master Mix (Applied Biosystems, Foster City, CA, USA) with uracil DNA-glycosylase (AmpErase UNG), and the mentioned specific TERT assay. Amplification conditions comprised an initial UNG incubation at 50ºC for 2 min, AmpliTaq Gold® DNA Polymerase activation at 95ºC for 10 min, 50 cycles of denaturation at 95ºC for 15 s and annealing/extension at 60ºC for 1 min.

For Peer Review

Each measurement in a sample was performed in triplicate for both TERT and TBP and the threshold cycle (C_t), the fractional number at which the amount of amplified target reached a fixed threshold, was determined. The standard deviation in sample triplicates was always below 0.2. Relative amounts of both genes were also normalized to a pool of control colonic tissue RNAs acting as calibrator to allow comparison across all tested samples. The comparative C_t method (Livak and Schmittgen 2001), also known as the $2^{-[delta][delta]Ct}$ method, was calculated from

$$[delta][delta]C_t = [delta]C_{t,sample} - [delta]C_{t,calibrator}$$

where $[delta]C_{t,sample}$ was the TERT C_t value for any sample normalized to TBP and $[delta]C_{t,\ calibrator}$ was the TERT C_t value for the calibrator also normalized to TBP. For the $[delta][delta]C_t$ calculation to be valid, the amplification efficiencies of the target and the endogenous reference must be approximately equal, being previously confirmed by checking how $[delta]C_t$ varied with template dilution for each tested genes. The

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

investigator performing the real-time quantitative PCR experiments was blinded with respect to the clinical characteristics of the patients.

Immunohistochemical Ki67 studies

Ki-67 myocardium activity was evaluated by inmunohistochemical assay on frozen myocardium tissue. Myocardium samples were fixed by ketone at-4ºC during 10 minutes, followed by PBS washing and serum blockade during 30 minutes. We used the commercial Ki 67-ihq-ap Monoclonal Mouse Anti-Human kid (TechMate/chemMate, Dako Cytomation, Carpinteria CA, USA). Lecture was performed with acid phosphatase staining. Primary antibody incubation was performed with the nuclear Ki-67 marker in a wet chamber, followed by washing and incubation with the secondary antibody linked to alkaline phosphatase for 30 minutes in a wet chamber. Finally the sample was submitted to gentle washing, revealed with substrate and counterstaining with hematoxilin. Evaluation of Ki-67 activity was performed by means of a semiquantitative study, evaluating the percentage of positive cells with respect to total evaluated myocardial cells. In each acase a mínimum of 3,000 myocytes were evaluated. We compared results from cases (alcoholics) with healthy donnors and also pathological controls either with hypertension or other causes of cardiomyopathy. All these procedures were supervised by an experienced pathologist.

Statistical Analysis

Standard statistical methods with the SPSS Statistical Analysis System V-16.0 were used. Differences between groups were analyzed using the ANOVA, Fisher's exact test, and the two-tailed Student's t-test. Correlation studies were obtained by Pearson's correlation coefficient. Since the variables followed a normal distribution, data are

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

expressed as mean ± SD, and a significance level of p less than 0.05 was used. Statistical software was Stata Corp. 2003. (Statistical Software: Release 8.1. College Station, TX: Stata Corporation, U.S.A).

RESULTS

Clinical data

After the selection period, we finally included 43 heart donors in the study. Fourteen heart donors had chronic hypertension, and 10 had CMP. Fifteen donors had a history of excessive alcohol consumption (> 60 g/ day, along more than 10 years), with 7 having CMP. Eight donors presented other causes of CMP (3 valve disease, 3 coronary and 2 of idiopathic origin). Finally, other 6 donors did not report previous ethanol consumption, and did not have arterial hypertension or other causes of cardiovascular disease (healthy controls).

The main clinical and epidemiological characteristics of cases and controls are reported in Table 1**.** The mean age of the donors was 55.8 ± 16.2 years, 32 cases (74.4%) being male and 11 (25.6%) female. There was a similar age and male/female ratio in the different groups of donors, with male predominance in all the groups. The BMI was similar in all groups, and no subjects fulfilled criteria of caloric malnutrition. The cardiothoracic index evaluated on chest X-ray was normal in the control group (0.48 ± 0.01) and enlarged in the other groups of donors, with donors with other causes of CMP being those with higher values (0.50 ± 0.06). Alcoholics and donors with hypertension showed comparable CTI (0.55 ± 0.06 and 0.56 ± 0.04, respectively).

Cardiac echosonography data in the control group showed normal left-ventricle ejection fraction (LVEF) (60.2 ± 5.1). Hypertensive donors showed a slight decrease in the LVEF (55.0± 14.4), that was clearly significantly decreased in the groups of alcoholics

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

(33.1 ± 20.7) and donors with other causes of CMP (34.6± 19.0), p<0.01 both. Evaluating NYHA functional class, all controls showed NYHA class I. NYHA II functional class predominated in the group of hypertensive donors, whereas NYHA I functional class predominated in alcoholics and other causes of CMP.

In the alcoholic donor group the mean daily alcohol consumption was 104.7 ± 48.4 g/day, being up to 60 g/day in all cases. The mean total lifetime dose of ethanol was 12.2 ± 5.4 Kg ethanol/Kg body weight. In all cases the period of alcohol consumption lasted more than 10 years, with a mean of 24.5 ± 6.4 years. Ethanol consumption in the other groups was significantly lower (p<0.01).

Ischemic or hemorrhagic stroke was the mean cause of death in the groups of hypertensive and alcoholic donors. In the other groups of donors, death was of diverse origin.

Myocardial proliferation studies

TERT expression

All 43 heart donor samples obtained were submitted to RNA extraction and subsequent monitorization of the *TERT* gene by real-time PCR, using the *TBP* gene as endogenous control. All these procedures were carefully controlled by an experienced technician. Purity and quality of samples were corroborated with the previously described procedures. The quantity of obtained RNA in each case was over 50 ng/µl, which is the minimum quantity considered to continue the study. Similarly, purity of samples was adequate in all cases (RNA integrity number (RIN) >8).

Real-time PCR amplifications in triplicate showed clear *TBP* gene expression in all cases. Notably, none of the samples showed significant TERT expression. The fact that the endogenous *TBP* gene was expressed in all samples can be considered a guarantee

For Peer Review

1
2
3 of good technical procedure, thus confirming that the lack of detection of TERT
4
5 expression is real, not a technical error.
6
7
8 Ki67 expression
9
10 Table 2 shows the results of Ki67 nuclear immunohistochemical expression. Healthy
11
12 controls were the group of donors with lower nuclear Ki-67 expression (3.92 ± 0.99 %
13
14
15 of positive myocytes). The group of alcoholics and hypertensive donors showed a
16
17 significant increase in Ki-67 expression, mainly in the subgroup of donors with CMP.
18
19
20 Similarly, the group of other causes of CMP showed a significant increase in Ki-67
21
22 expression compared to controls, in a similar range as the subgroups of alcohol and
23
24
25 hypertensive donors with CMP. Table 2 also reflects the degree of increase in Ki-67
26
27 expression with respect to controls in each group of donors. Thus, we observe a 2.5 fold
28
29
30 increase in the group of hypertensive and alcoholic donors without CMP. The presence
31
32 of CMP, independently of the cause, was a clear factor of increase in Ki-67 nuclear
33
34 expression. Thus, alcoholics with CMP showed a 3.2-fold increase, hypertensive donors
35
36
37 with CMP a 3.4-fold increase, and other causes of CMP a 4-fold increase with respect to
38
39 healthy controls (Table 2).
40
41 Healthy control donors showed a significantly lower Ki-67 expression compared to all
42
43
44 the other groups of donors with CMP, either of alcoholic, hypertensive or of other
45
46 causes (p< 0.01 in all cases). On comparing the different groups of donors with CMP,
47
48
49 alcoholics were those with the lowest Ki-67 nuclear expression, followed by
50
51 hypertensive CMP and other causes of CMP. However, differences between groups of
52
53 donors with CMP did not achieve significance (P> 0.800 in all cases).
54
55
56 In the groups of hypertensive donors, those with CMP showed a higher but non-
57
58 significant increment in Ki-67 nuclear expression compared to those without CMP
59
60 (13.51 ± 3,56 vs 9.90 ± 5.80 %, respectively, (P=0.805). Similarly, in the groups of

For Peer Review

alcoholics, those with CMP showed a non-significant increase in Ki-67 nuclear expression (12.81 ± 4.99 vs 9.92 ± 5.36 %, respectively, (P= 0.859)..

According to the present results, the absence of significant telomerase gene expression in these samples does not allow a possible correlation with the Ki-67 nuclear antigen expression, the other marker of cardiac myocyte proliferation, to be established.

DISCUSSION

The present study demonstrates the activation of the Ki-67 cell proliferation marker in cardiac myocytes from donors with alcoholic and other causes of CMP such as those of hypertensive, valve, coronary or idiopathic origin. However, TERT expression was not useful to detect this proliferation activity in this specific biological model.

Previous studies have clearly corroborated the role of alcohol in inducing apoptosis and cell-death mechanisms in cardiac myocytes (Molina et al, 2002; Fernández-Solà et al, 2006). Although a clear dose-dependent effect of ethanol inducing left-ventricular dysfunction has been described, not all alcohol misusers develop dilated CMP. Thus, subjects with similar quantity of cumulated lifetime alcohol consumption may develop diverse degrees of ventricular dysfunction. Therefore, in addition to the toxic effect of ethanol causing apoptosis, necrosis and cell loss, other mechanisms may influence the development of cardiac functional and structural damage (Urbano-Márquez et al, 1995; Fernández-Solà et al, 2002, 2008).

Recent evidence of cardiac myocyte proliferation led us to consider the possibility that some repair mechanism may modulate the degree of ventricular damage induced by ethanol. The concept of cardiac homeostasis and plasticity would consider an equilibrium between both damaging and repair mechanisms, sometimes acting synchronically (Nadal-Ginard et al. 2003a; Buja and Vela, 2008). In fact, cell-death

For Peer Review

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60

mechanisms probably activate the proliferation response themselves (Hotchkiss et al, 2009).

Previous studies have shown the influence of ethanol decreasing myocyte proliferation after heart damage, as evaluated by myocyte Ki-67 immunohistochemical activity. This effect may act through diverse mechanism, implicating up-regulation of myocyte myostatin activity (Fernández-Solà et al, 2008). Other studies in animal and human models have evidenced the relevance of TERT expression and telomere function in maintaining the cell replication potential (Djojosubroto et al, 2003; Anversa et al, 2005) Human telomere length shortens in diverse situations such as endothelial cells from atherosclerotic plates, in hypertrophic myocardium tissue, in end-stage heart failure and in leukocytes from subjects with cerebrovascular disease, hypertension, diabetes or acute myocardium infarction (Fuster and Andrés, 2006). Other *in vitro* studies with dog cardiomyocytes showed a relationship between TERT activity, Ki-67 expression and cardiac dysfunction (Leri et al, 2001).

In the present study we hypothesized that TERT expression could a useful approach to evaluate the degree of heart myocyte proliferation. Although TERT has been used to evaluate cell proliferation in diverse experimental and clinical situations (Djojosubroto et al,2003; Leri et al, 2000, 2003; Urbanek et al, 2005; Oh et al, 2001), no specific studies on TERT expression in alcoholic CMP have previously been performed.

Studies of TERT and other proliferation markers such as Ki67 expression performed in ischemic CMP, hypertension and atherosclerosis showed paradoxical results. In fact, it is debated whether TERT activity and telomere shortening are independent factors or only a consequence of cardiovascular tissue damage (Fuster and Andres, 2006). This discrepancy in results led Anversa et al (2005) to suggest the use of more than one proliferation marker in myocyte studies.

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

In cultured human embryo cardiomyocytes TERT independent mechanisms such as expression of p16 protein and beta-galactosidase activity were able to accelerate or decrease the process of cell senescence and death (Ball and Levine, 2005). In healthy adult heart tissue, TERT expression is not present or is slightly expressed because of its low proliferation capacity. The cell renewal myocyte index in the human heart has not been clearly established, and some factors such as individual age and the presence of heart damage may influence its presentation (Hosoda et al, 2010). In an interesting study, using DNA-integrated C^{14} Bergmann et al (2009) calculated a renewal percentage of 0.2-2% per year in healthy individuals. This percentage clearly diminishes along the senescence process. Thus, a 25-year-old subject has 1% /year renewal percentage and a 75-year-old subject 0.45%. Buja and Vela (2008) approximated a regenerative percentage of healthy cardiac myocytes of 0.0014% (14 myocytes per 1 million). In end-stage heart failure, this index is 0.013 to 0.015%, and is 0.03%.in neighboring necrotic areas after myocardium infarction.

Thus, several studies have clearly corroborated the existence of some capacity of the adult human myocardium to establish proliferation response. However, the degree of this myocyte proliferation response may be modified by different factors such as age, toxic habits, presence of cardiac disease such as hypertension or coronary disease (Anversa et al, 2004, 2005; Beltrami et al, 2003).

In the present study we expected to find increased myocyte proliferation either shown by Ki-67 expression or TERT activity in donors, mainly in those affected of CMP. We found significant increase in Ki-67 activity in donors with CMP of diverse origin, with a relatively lower increase in activity in alcoholics compared to other causes of CMP. This result is in concordance to that described in a previous study (Fernández-Solà et al, 2008). However, we were not able to detect TERT expression in any of the 43 heart

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

samples studied. We detected a clear activity of the control *TBP* gene, a fact that validates the technical procedure. Notably, real-time PCR constitutes a more sensitive technology than the telomeric repeat amplification protocol (TRAP), used in previous similar studies (Oh H et al, 2001). The quantity, purity and adequacy RNA samples were clearly corroborated and validated. In relation to this subject, a previous study of de Kok et al (2000) evaluating TERT expression by RT-PCR in human tissues, detected increased TERT expression in diverse tumoral tissues, but low activity in healthy tissues (lung, esophagus and colon), and null expression in pancreas and bladder tissues. Since myocardium has lower proliferation activity than the healthy tissues examined null TERT expression in heart tissue was also expected.

According to the results obtained, we can conclude that TERT expression evaluated by real-time PCR in human heart samples is not a good marker of myocyte proliferation in this biological model, since no activity was detected in any of the samples that were otherwise positive for Ki-67 proliferation activity. Diverse reasons may explain these results. One is the possibility that proliferation is a limited tissue response that may be exhausted after a period of persistence of lesion. In the case of ethanol cardiac damaging effect, diverse mechanisms regulate the interaction between induction of apoptosis and cell death and the reparative proliferation response (Molina et al, 2002). Some of theses mechanisms may even be counterpoised. Finally, we have shown evidence that ethanol decreases the compensatory proliferation response that may be inhibited in these cases. Proliferative response of myocardium also depends on the type of lesion. Thus, in human cardiac myocytes Kubo et al (2008) found an increase in cardiac stem cells in the more affected hearts. However, in the situation of heart ischemia, inflammation or oxidative stress this endogenous myocardial renewal was clearly limited.

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Since one of the limitations in the present study is the relative small number of samples because of the difficulty in obtaining human heart tissue, it is possible that an increase in the sample number might show more evident and significant results. It is of note that the model of alcoholic CMP in donors is different from that performed in clinical series of subjects, in which the degree of alcohol consumption and the clinical relevance of the CMP was clearly higher (Urbano-Márquez et al, 1989; 1995; Nicolás et al, 2002; Fernández-Solà et al, 1997, 2002). Another difference may be that our study analyzed causes of diffuse heart damage either of alcoholic, hypertensive, or other origin. Most previous studies have been performed in the model of ischemic heart damage where localization of damage is more focal and intense. Finally, Ki-67 and TERT activities may be measured by different technical procedures that may provide somewhat different results.

Considering the results from the present as well as other previous studies in alcoholic CMP, we suggest the necessity to design and develop further approaches to explain the complex mechanisms that regulate cell death and proliferation response in alcoholics with dilated CMP. Other regulatory mechanisms such as myostatin (McNally,2004; Wagner et al, 2005; Yang et al, 2005) or IGF-1 activities (Ahuja et al, 2007) probably contribute to maintain cardiac homeostasis and plasticity in the heart of alcohol misusers. Better knowledge of myocyte cell cycle control may allow the use of stem cells therapy that could allow myocardial renewal (Taylor,2004; Von Harsdorf et al,2004; Regula et al,2004).

For Peer Review

REFERENCES

Ahuja P, Sdek P, Maclellan R (2007) Cardiac myocyte cell cycle control in development, disease and regeneration. Physiol Rev 87:521-544.

Anversa A, Kajstura J (1998) Ventricular Myocytes are not terminally differentiated in the adult mammalian heart. Circ Res 83:1-14.

Anversa P, Nadal-Ginard B (2002). Myocyte renewal and ventricular remodeling. Nature 415: 240-243.

Anversa P, Sussman M, Bolli R (2004) Molecular genetic advances in cardiovascular medicine. Circulation 109: 2832-2838.

Anversa P, Rota M, Urbanek K, Hosoda T, Sonnenblick EH, Leri A, Kajstura J, Bolli R (2005) Myocardial aging. A stem cell problem. Basic Res Cardiol 100(6):482-493.

Ball AJ, Levine F (2005) Telomere-independent cellular senescence in human fetal cardiomyocytes. Aging Cell 4(1):21-30.

Beltrami A,Urbanek K, Kajstura J, Yan S, Finato N, Bussani R, Nadal-Ginard B, Silvestri F, Leri A, Beltrami C, Anversa P (2001) Evidence that human cardiac myocytes divide after myocardial infarction. N Engl J Med 344:1750-1757.

Beltrami A, Barlucchi L, Torella D, Baker M, Limana F, Chimenti S, Kasahara H, Rota M, Musso E, Urbanek K, Leri A, Nadal-Ginard B, Anversa A (2003) Adult cardiac stem cells are multipotent and support myocardial regeneration. Cell 114: 763-776.

Bergmann O, Ratan D, Bernard S, Zdunek S, Barnabé-Heider F, Walsh S, Buchholz BA, Druid H, Jovinge S, Frisén J (2009) Evidence for cardiomyocyte renewal in humans. Science 324: 98-102.

Blasco MA (2005) Telomeres and human disease: ageing, cancer and beyond. Nat Rev Genet 6(8):611-622.

Buja L, Vela D (2008) Cardiomyocyte death and renewal in the normal and diseased heart. Cardiovascular Pathology 17:349-374.

de Kok JB, Ruers TJ, van Muijen GN, van Bokhoven A, Willems HL, Swinkels DW (2000) Real-time quantification of human telomerase reverse transcriptase mRNA in tumors and healthy tissues. Clin Chem 46(3):313- 318.

Djojosubroto MW, Choi Y, Lee H, Rudolph K (2003) Telomeres and telomerase in aging, regeneration and cancer. Mol Cells 15(2):164-175.

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Fernández-Solà J, Estruch R, Grau JM, Pare JC, Rubin E, Urbano-Márquez A (1994) The relation of alcoholic myopathy to cardiomyopathy. Ann Intern Med 120(7): 529 - 536.

Fernández-Solà J, Estruch R, Nicolas JM, Paré JC, Sacanella E, Urbano-Márquez A (1997) Comparison of alcoholic cardiomyopathy in women versus men. Am J Cardiol 80(4):481-485.

Fernández-Solà J, Nicolás JM, Oriola J, Sacanella E, Estruch R, Rubin E, Urbano-Márquez A (2002) Angiotensin-converting enzime gene polimorphism is associated with vulnerability to alcoholic cardiomyopathy. Ann Intern Med 137: 321-326.

Fernández-Solà J, Fatjó F, Sacanella E, Estruch R, Bosch X, Urbano-Márquez A, Nicolas JM (2006) Evidence of apoptosis in alcoholic cardiomyopathy. Hum Pathol 37: 1100-1110.

Fernández-Solà J, Sacanella E, Estruch R, Lluis M, Antúnez E, Urbano-Márquez A (2008) Factors influencing myocyte death and regeneration in alcoholic cardiomyopathy. Alcohol Clin Exp Res (Supll) 38 (6): 308A.

Fernández-Sola J, Lluis M,, Sacanella E, Antúnez E, Estruch R, Urbano-Márquez A (2010) Increased myostatin activity and decreased myocyte proliferation in chronic alcoholic cardiomyopathy. Alcohol Clin Exp Res 2010 (in press)

Fuster JJ, Andrés V (2006) Telomere biology and cardiovascular disease. Circ Res 99:1167-1180.

Gerder A (2002) Cardiac myocyte remodeling in hypertrophy and progression to failure. J Cardiac Failure 8(1): S264-S268.

Goldman L, Hashimoto B, Cook EF, Loscalzo A (1981) Comparative reproducibility and validity of assessing cardiovascular functional class: advantages of a new specific activity scale. Circulation 64:1227- 1233.

Gottdiener JS, Berdnarz J, Devereux R, Gardin J, Klein A, Manning WJ, Morehead A, Kitzman D, Oh J, Quinones M, Schiller NB, Stein JH, Weissman NJ (2004) American Society of Echocardiography recommendations for use of echocardiography in clinical trials. J Am Soc Echocardiogr 17: 1086- 1119.

Hill J, Olson E (2008). Mechanisms of disease: cardiac plasticity. N Engl J Med 358 (13):1370-80.

Hosoda T, Kajstura J, Leri A, Anversa P (2010) Mechanisms of myocardial regeneration. Circ J 74(1): 13-17.

Hotchkiss RS, Strasser A, McDunn JE, Swanson PE (2009) Cell death. N Engl J Med 361(16):1570-1583.

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Jänkälä A, Eriksson P, Eklund K, Härkönen M, Mäki T (2002) Combined calcium carbimide and ethanol treatment induces high blood acetaldehyde levels, myocardial apoptosis and alters expression of apoptosis-regulating genes in rat. Alcohol Alcohol 37(3): 222-228.

Jopling Ch, Sep E, Raya M, Martí M, Raya A, Izpisua-Belmonte JC (2010) Zebrafish heart regeneration occurs by cardiomyocyte dedifferentiation and proliferation. Nature 464: 606-611.

Kajstura J, Leri A, Finato N, DiLoreto C, Beltrami CA, Anversa P (1998) Myocyte proliferation in end-stage cardiac failure. Proc Natl Acad Sci 95: 8801-8805.

Kajstura J, Leri A, Castaldo C, Nadal-Ginard B, Anversa P (2004) Myocyte growth in the failing heart. Surg Clin North Am 84(1):161-177.

Kubo H, Jaleel N, Kumarapeli A, Berretta R, Bratinov G, Shan X, Wang H, Houser SR, Margulies KB (2008). Increased cardiac myocyte progenitors in failing human heart. Circulation 118: 649-657.

Leri A, Malhotra A, Liew C, Kajstura J, Anversa P (2000). Telomerase activity in rat cardiac myocytes is age and gender dependent. J Mol Cell Cardiol 32: 385 -390.

Leri A, Barlucchi L, Limana F, Deptala A, Darzynkiewicz Z, Hintze T, Kajstura J, Nadal-Ginard B, Anversa P (2001) Telomerase expression and activity are coupled with myocyte proliferation and preservation of telomeric length in the failing heart. Proc Natl Acad Sci USA 98(15): 8626 - 8631.

Leri A, Franco S, Zacheo A, Barlucchi L, Chimenti S, Limana F, Nadal-Ginard B, Kajstura J, Anversa P, Blasco M (2003) Ablation of telomerase and telomere loss leads to cardiac dilatation and heart failure associated with p53 upregulation. EMBO Journal 22(1):131-139.

Livak KJ, Schmittgen TD (2001). Analysis of relative gene expression data using real-time quantitative PCR and the 2(-Delta Delta C(T)) method. Methods 25(4):402-408.

Magdelénat H (1992). Tumour markers in oncology: past, present and future. HJ Immunol Methods 150(1-2):133-143.

McNally E (2004) Powerful genes-myostatin regulation of human muscle mass. N Engl J Med 350: 2642-2644.

Molina P, McClain P, Valla D, Guidot D, Diehl A, Lang C, Neuman M (2002) Molecular pathology and clinical aspects of alcohol-induced tissue injury. Alcohol Clin Exp Res 26(1):120-128.

Nadal-Ginard B, Kajstura J, Anversa P, Leri A (2003a) A matter of life and death: cardiac myocyte apoptosis and regeneration. J Clin Invest 111:1457-1459.

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Nadal-Ginard B, Kajstura J, Anversa P, Leri A (2003b). Myocyte death, growth and regeneration in cardiac hypertrophy and failure. Circ Res 92: 139-150.

Nicolás JM, Fernández-Solà J, Estruch R, Paré JC, Sacanella E, Urbano-Márquez A, Rubin E (2002) The effect of controlled drinking in alcoholic cardiomyopathy. Ann Intern Med 136(3):192-200.

Oh H, Taffet G, Youker K, Entman M, Overbeek P, Michael Ll, Schneider M (2001) Telomerase reverse transcriptase promotes cardiac muscle cell proliferation, hypertrophy and survival. Proc Natl Acad Sci U S A 98(18):10308-10313.

Piano MR (2002). Alcoholic Cardiomyopathy. Chest 121(5):1638-1650.

Quaini F, Urbanek K, Graiani G, Lagrasta C, Maestri R, Monica M, Boni A, Ferraro F, Delsignore R, Leri A; Kajstura J, Anversa P (2004) The regenerative potential of the human heart. Int J Cardiol 95: S26-S28.

Regula K, Rzeszutek J, Baetz D, Seneviratne Ch, Kirshenbaum A (2004) Therapeutic opportunities for cell cycle re-entry and cardiac regeneration. Card Res 64:395-401.

Serrano AL, Andrés V (2004) Telomeres and cardiovascular disease: does size matter? Circ Res 94(5): 575 - 584.

Sobel LC, Maisto SA, Sobell MB, Cooper AM (1979). Reliability of alcohol abusers' self-reports of drinking behaviour. Behav Res Ther 17:157- 160.

Soonpaa M, Field L (1998) Survey of studies examining mammalian cardiomyocyte DNA synthesis. Circ Res 83:15-26.

Taylor D (2004) Cell-based myocardial repair: how should we proceed? Int J Cardiol 95:S8-S12.

Urbano-Márquez A, Urbano-Márquez A, Estruch R, Navarro-López, Grau JM, Mont L, Rubin E (1989) The effects of alcoholism on skeletal and cardiac muscle. N Engl J Med 320:409-411.

Urbano-Márquez A, Estruch R, Fernández-Solà J, Nicolás JM, Paré JC, Rubin E (1995) The greater risk of alcoholic cardiomyopathy and myopathy in women compared with men. JAMA 274 (2):149-154.

Urbano-Márquez A, Fernández-Solà J (2004) The effect of alcohol on cardiac and skeletal muscle. Muscle Nerve 30: 689-707.

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Urbanek K, Quaini F, Tasca G, Torella D, Castaldo C, Nadal-Ginard B, Leri A, Kajstura J, Quaini E, Anversa P (2003) Intense myocyte formation from cardiac stem cells in human cardiac hypertrophy. Proc Natl Acad Sci U S A 100(18):10440-10445.

Urbanek K, Torella D Sheikh F, De Angelis A, Nurzynska D, Silvestri F, Beltrami CA, Bussani R, Beltrami AP, Quaini F, Bolli R, Leri A, Kajstura J, Anversa P (2005) Myocardial regeneration by activation of multipotent cardiac stem cells in ischemic heart failure. Proc Natl Acad Sci USA 102(24): 8692-8697.

Von Harsdorf R, Poole-Wilson P, Dietz R (2004) Regenerative capacity of the myocardium: implications for treatment of heart failure. Lancet 363:1306-1313.

Wagner K, Liu X, Chang X, Allen R (2005) Muscle regeneration in the prolonged abscence of myostatin. Proc Natl Acad Sci USA 102(7): 2519-2524.

Yang W, Zhang Y, Ma G, Chen Y, Zhu D (2005) Identification of gene expression modifications in myostatin-stimulated myoblasts. Biochem Biophys Res Com 326 (3): 660-666.

For Peer Review

Table 1. Epidemiologic, clinical and heart function data of the different groups of donors.

	Healthy control donors n= 6	Donors with other causes of cardiomyopathy n= 8	Hypertensive Donors n= 14	Alcoholic donors n= 15
Gender (male/female ratio)	4:2	6:2	10:4	12:3
Age (years)	55.8 ± 16.2	57.9± 13.3	61.3 ± 11.2	55.5 ± 11.2
Body mass index (Kg/cm^2)	25.9 ± 3.60	26.9 ± 3.05	27.4 ± 3.33	27.4± 4.59
Cardiothoracic index	0.48 ± 0.01	0.58± 0.06	0.56± 0.04	0.55 ± 0.06
Left-ventricular ejection fraction (%)	60.2 ± 5.1	34.6± 19.0**	55.0± 14.4	33.1± 20.7**
NYHA function class (n)				
I	6	5	4	8
II	0	2	7	6
III and IV	0	1	3	1
Daily ethanol consumption (g/day)	0	7.50 ± 21.2	5.3 ± 12.,9	104.7 ±_4.,4*
Total Lifetime Dose of Alcohol (Kg EtOH/Kb body weight)	0	1.22± 3.46	0.82 ±_ 1.30	12.2 ± 5.40*
Period of ethanol consumption (years)	0	2.50 ± 7.07	3.22 ± 1.23	24.5 ± 6.41*
Cause of death (n)				
Cerebrovacular	3	3	13	10
Cranial trauma	3	0	0	1
Other	0	5	1	4

Results expressed as mean ± SD

* p<0.01 compared to the other groups

** p<0.01 compared to controls

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 2. Cardiac myocyte Ki67 expression and TERT activity in different subgroups of donors

	Healthy control donors n=6	Hypertensive donors without CMP n=4	Hypertensive donors With CMP n=10	Alcoholic donors without CMP n= 8	Alcoholic donors with CMP n=7	Donors with other causes of CMP n=8
Ki67 (% of positive cells)	3.92 ± 0.99*	9.90 ± 5.80	13.5 ± 3.56**	9.92 ± 5.36	12.8 ± 4.99***	15.9 ± 2.21
Increasing of ki67 expression with respect to healthy controls		x 2.5	x 3.4	x 2.5	x 3.2	x 4.0
TERT activity (% of positive cells)	0	0	0	0	0	0

Results expressed as mean ± SD

CMP: Cardiomyopathy

* p <0.01 compared to the other groups with CMP

** p= 0.805 compared to hypertensive donors without CMP

*** p= 0.859 compared to alcoholic donors without CMP

er Review

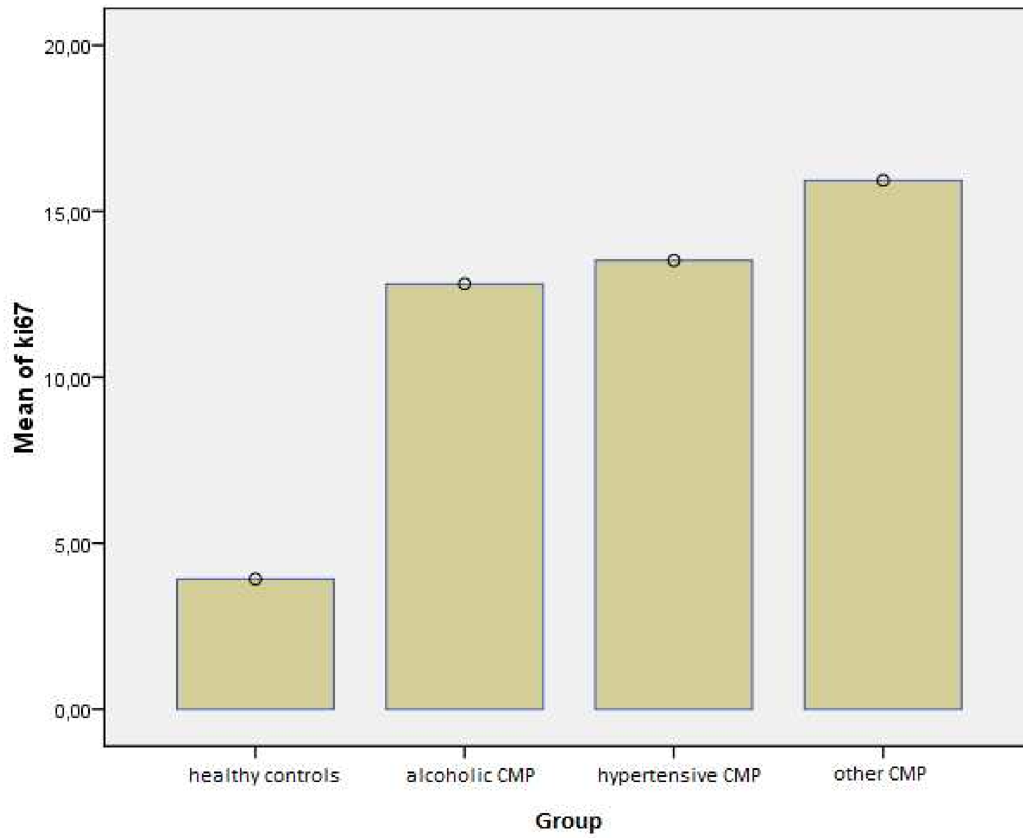
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For Peer Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Figure 1. Cardiac Ki67 expression in the different groups of heart donors

Figure 1a. Expression of Ki67 antigen in healthy control donors compared to donors with cardiomyopathy of alcoholic, hypertensive or other causes

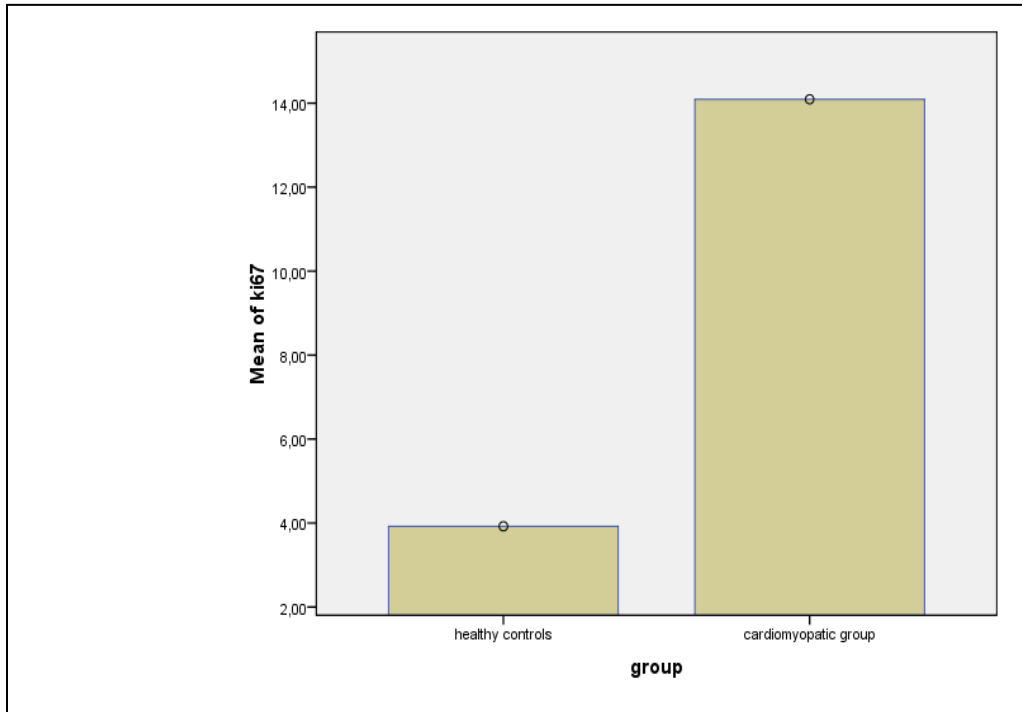


CMP: cardiomyopathy
Results expressed as percentage of positive cells

view

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Figure 1b. Ki67 expression in healthy controls compared to all donors with cardiomyopathy



Statistically significant difference ($p < 0.01$)

Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Figure 2. Ki67 heart immunohistochemical assay.

2.a. Control donor with low Ki-67 nuclear activity (magnification x 250)

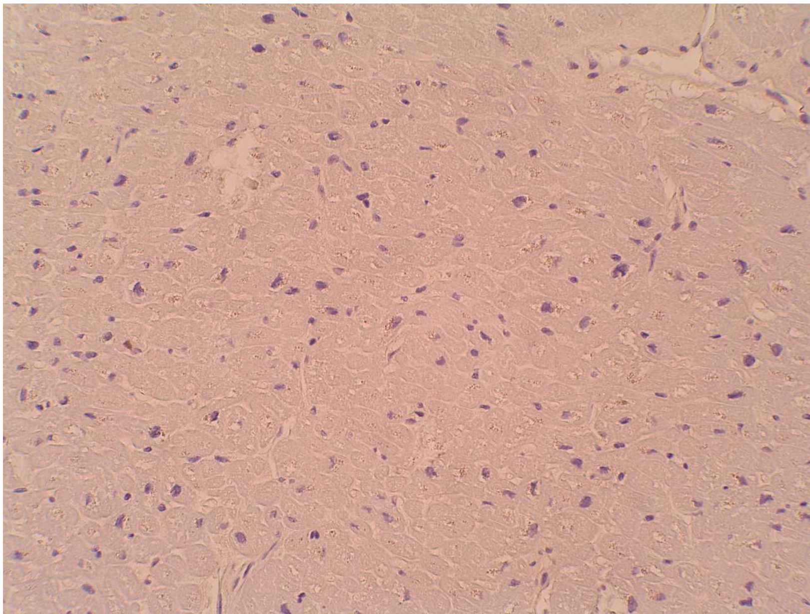
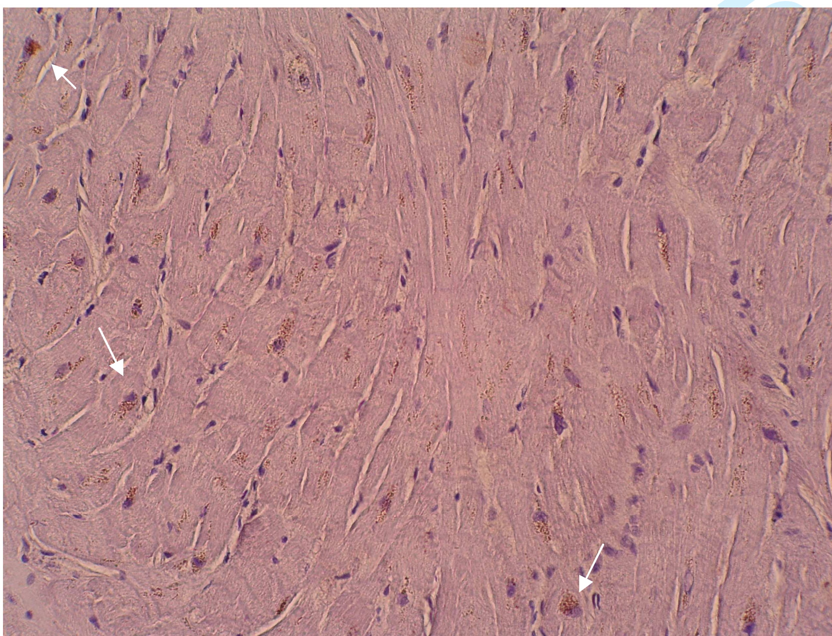


Fig 2.b. Alcoholic donor with cardiomyopathy.
Increased Ki-67 activity is evident in some nuclei (arrows)
(magnification x 250)



Review