Left Ventricular Twist in Children
--- Does LV Rotation Change with Aging in Children? ---

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Left Ventricular Twist in Children
--- Does LV Rotation Change
with Aging in Children? ---

Directed by Professor Jun Hee Sul

The Master's Thesis

Submitted to the Department of Medicine,

The Graduate School of Yonsei University

in partial fulfillment of the requirements for the degree of

Master of Medical Science

Lucy Youngmin Eun

December 2007

This certifies that the Master's Thesis

of Lucy Youngmin Eun is approved.

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The Graduate School

Yonsei University

December 2007

ACKNOWLEDGEMENTS

I feel a great pleasure and pride for the master's course and a small piece of academic accomplishment. For my master's course, Professor Jun Hee Sul sincerely guided me with enthusiasm and joy. I'm deeply grateful and would like to pay respect to him. Also, professor Young Hwan Park helped me by doing all for this work in right way, and professor Seok-Min Kang was willing to give his wonderful advice to me as committee members.

It is needless to say that this thesis would not have been possible without the dedication of my family. My mother always supported, since childhood, my intellectual curiosity with encouragement and enthusiasm, for which I deeply appreciated. And my belated father gave me strength and power to keep this work with his love. My parents-in-law encouraged me as well. Most of all, no word of appreciation is enough for the love and support of my husband Han Seok Kim. It was his patience and devotion that made me feel secure throughout the process.

During my master's course, Lord prepared everything and showed me the best way to go. I could not have finished this work without God's love. I thank God and pay glory to the Lord. I owed to the Lord for my honesty and faithfulness.

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Abstract

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Background The recently introduced method, speckle tracking echocardiography, represents simplified, objective, and angle-independent modality for quantification of regional myocardial deformation. As published, there was no significant change in LV torsion with aging, there might be some difference in LV rotation at base and apex. The purpose of this study was to assess the relationship of LV rotation for torsion with aging in children.

Methods Forty healthy children were recruited and divided into two groups of twenty preschool age (2 ~ 6 years of age) and twenty school age children (7 ~ 12 years of age). After obtaining conventional echocardiographic data, apical and basal short axis rotations were assessed with speckle tracking echocardiography.

LV rotations in basal and apical short axis planes were determined of six myocardial segments along the central axis.

Results There was no significant change in apical and basal LV rotation with age between preschool and school age children. However, there was a certain trend between two age groups in each basal and apical rotation. In basal and apical rotation, the values of preschool age children are greater than those of school age children at anteroseptal, anterior, lateral, posterior, inferior, and septal all six segments.

Conclusion There was some trend of incremental rotation value in preschool age children rather than school age children. Although there was no statistically significant age-related change in LV rotation between these two groups, the decrease trend with aging for rotation and torsion twist during childhood should be necessary for further investigation.

Key Words : children: LV rotaion: LV torsion: age difference

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I. INTRODUCTION

Current research in clinical cardiac mechanics is upgraded from short axis and long axis left ventricular function and ejection fraction to three-dimensional ventricular deformation studies, including left ventricular torsion. [1, 2] Left ventricular torsional deformation, based upon the helical myocardial fiber architecture, is an important role with respect to LV ejection and filling performance.[3 - 6] During the cardiac cycle, there is a systolic twist and an early diastolic untwist of the LV about its long axis because of oppositely directed apical and basal rotations. The magnitude and characteristics of this torsional deformation are well established that LV rotation is sensitive to changes in regional and global LV function. [7 - 19]

Therefore, interpretation of LV rotation represents an accurate approach for quantifying LV function. However, there is no comprehensive study describing its normal development during childhood respect to age-related change.

In systole, the LV apex rotates counterclockwise, whereas the base rotates clockwise, creating a torsional deformation originating in the dynamic interaction of appositely wound epicardial and endocardial myocardial fiber helices.[2] One of the special characteristics of static B-scan ultrasound imaging is an appearance of speckle patterns within the tissue, which are the result of constructive and destructive interference of ultrasound back-scattered from structures smaller than a wavelength of ultrasound. Motion analysis by speckle tracking has been attempted using block-matching and autocorrelation search algorithms, and speckle motion has been closely linked to underlying tissue motion when small displacements are involved.[20 - 22]

A recently developed noninvasive echocardiographic speckle tracking imaging (STE) technique, as a novel ultrasound method for quantification of true 2D heart motion independent of borders, Doppler or its beam angles, has been a method for assessment and quantification of LV rotation and torsion.[23]

LV torsion and untwisting showed age-related increases in general, and when normalized by LV length, they demonstrated larger values in infancy and middle age. Notomi et al suggested that net LV torsion increases gradually from infancy to adulthood, but the determinants of this were different. [24]

The neonatal myocardium develops less force than does that of the adult, and cardiocytes increase both myofibrillar and sarcoplasmic reticulum contents after birth.[24 - 26] Large changes in hemodynamic load occur during cardiac development and are associated with increased contractility owing to alterations in the relative expression of sarcoplasmic protein isoforms.[27] The giant sarcoplasmic protein 'spring' that both resists passive stretch and helps the myocyte to recoil after contraction.[28] In addition to these cardiac changes, arterial distensibility decreases from childhood to adulthood, a stiffening of the arterial tree that increases afterload even in normotensive individuals.[29, 30]

In this study, we sought to investigate the alterations in LV torsional behavior from preschool age to school age children in normal childhood.

II. MATERIALS AND METHODS

Study participants

This study population consisted of 40 children, aged 2 years to 14 years from January 2007 till August 2007, and divided into two groups, one group of twenty preschool age children (2 years to 6 years, mean age 4.5 ± 1.2), the other group of twenty school age children (7 years to 14 years, mean age 10.5 ± 2.7).

They were recruited from children referred for electrocardiography or echocardiography to evaluate cardiac murmur, chest pain, and syncope. All subjects were normotensive and clinically well from a cardiovascular standpoint, in normal sinus rhythm with a normal surface ECG, without structural and functional abnormalities on the transthoracic echocardiography. They were free from past or present systemic disease.

Echocardiography

The main echocardiographic examinations were performed with Vivid 7 scanner (GE Vingmed Ultrasound, Horten, Norway) equipped with a phased-array transducer. Transducer frequencies, sampling rates, and sector width were adjusted for optimal speckle quality of the recordings. LV short axis recordings were aquired. In this study, the proper short axis levels were defined as follows: at the basal level, by the presence of mitral valve, and at the apical level, LV cavity alone with no papillary muscles. The LV cross section was made as circular as possible.

The analyses were performed on a computer with customized software within the EchoPac platform (GE Medical Systems, Milwaukee, Wisconsin, USA).

Conventional echocardiograms were evaluated for LV systolic and diastolic function. After completion of standard comprehensive examinations, to assess LV longitudinal myocardial motion, tissue Doppler imaging (TDI) analysis was performed offline, and the myocardial tissue velocity profile was obtained from an optimal measuring position set at the basal segment of septum and LV lateral wall from apical four chamber projections. The mean frame rate was 150 - 180 frames per second, and the velocity range was 12 to 20 cm/sec to avoid aliasing for TDI aquisition. The measurements of maximal systolic and early diastolic velocities were obtained.

In addition, at basal and apical short axis level, radial transverse and circumferential strain values were obtained using EchoPac program as well.

LV Rotation and Torsion

Spectral tracking echocardiography was performed for offline analysis, then LV rotation was defined as angular displacement of LV about its central axis in the short-axis image. These data were demonstrated in units of degree.

LV torsion was defined as a net difference of global LV rotation between apical and basal short axis planes at each time point, and calculated as the following equation. [31, 32]

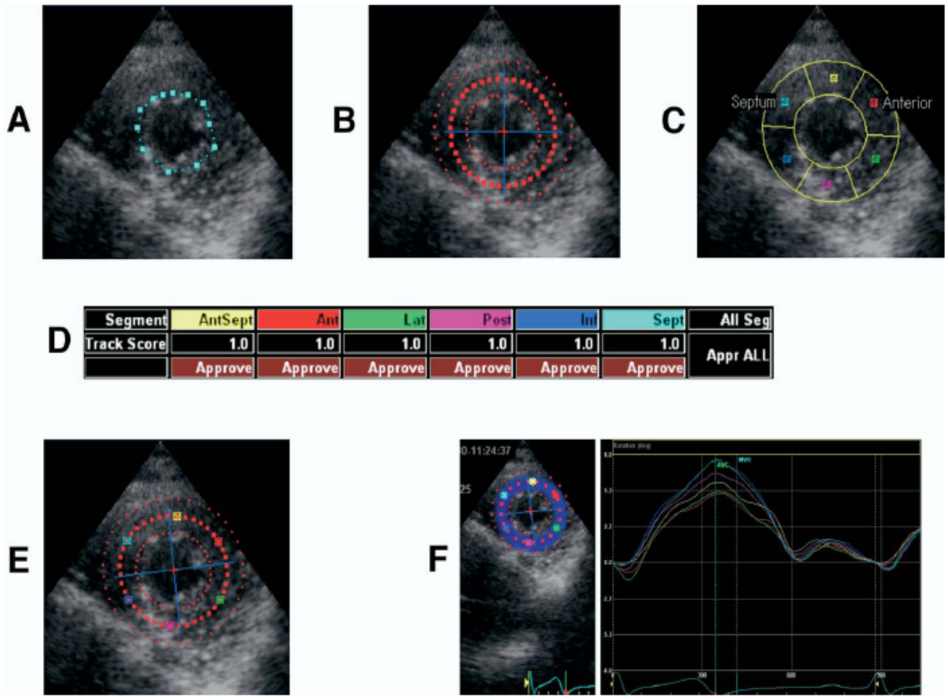
Global torsion = Apical global rotation – Basal global rotation

Peak global torsion was defined as the maximal value of global torsion during the cardiac cycle.

Statistical Analysis

All data were expressed as mean ± SD. Statistical analysis was performed by student's t-test. Relationships were considered statistically significant when *p* value was less than 0.05.

Figure 1. Measurement process of left ventricular rotation by 2-dimensional speckle tracking echocardiographic imaging. A to F, Measuring LV rotation in apical short axis view.

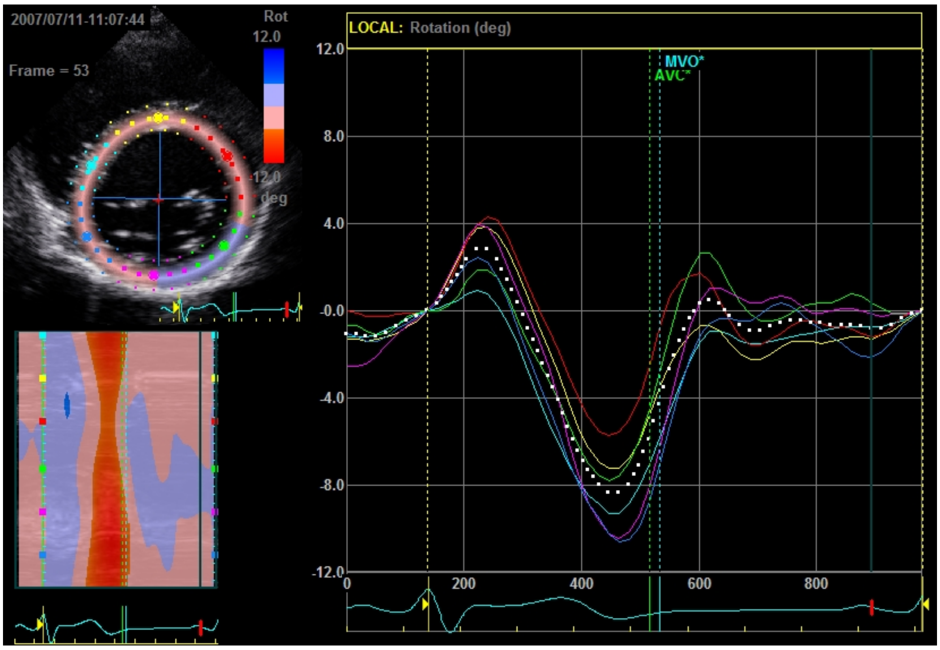


III. RESULTS

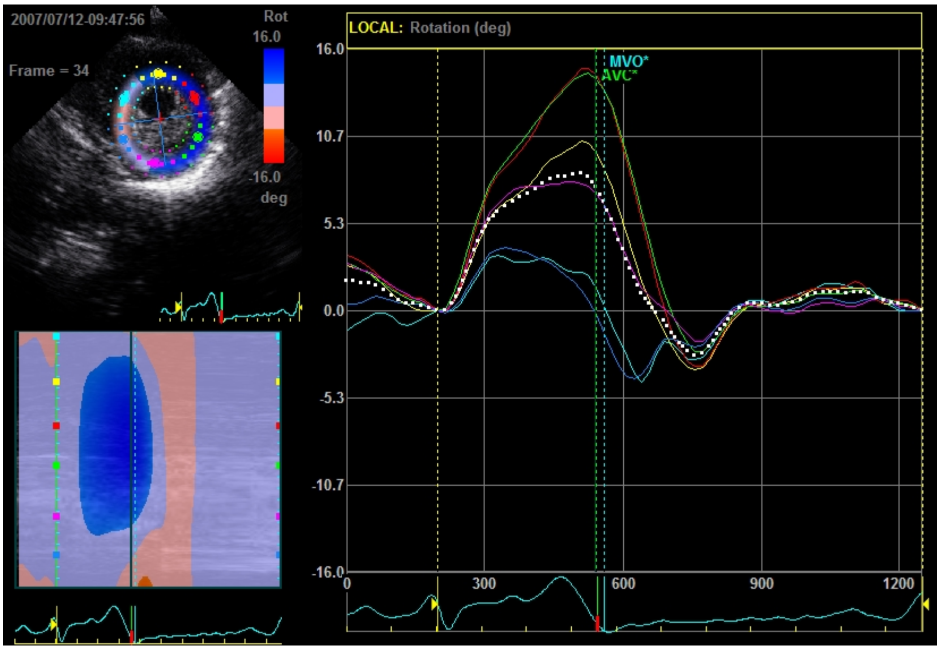
We divided the study population into 2 groups, twenty preschool children (2 ~ 6 years) and another twenty school age children (7 ~ 14 years). Significant growth and a corresponding fall in heart rate with relatively constant blood pressure were observed with aging in these children. From conventional echocardiographic measures, LV ejection fraction (67.0 ± 2.0 vs 66.5 ± 5.4, p = ns) and LV wall thickness index (0.25 ± 0.05 vs 0.23 ± 0.02, p = ns) were not different between two groups.

Figure 2. Rotation data were aquired with speckle tracking echocardiography for a) basal clockwise rotation, and b) apical counterclockwise rotation, offline analysis at two dimensional short axis view.

a)



b)



LV Rotation Patten

In this study, basal and apical rotation data demonstrated higher in preschool age children than those of school age children.

Apical rotation is consistently counterclockwise, presented as positive value, changing slightly from preschool age to school age without statistical significance, whereas basal rotation shows clockwise direction of negative value, more significant changes with aging ($p < 0.05$), especially at inferior and septal segments ($p < 0.02$).

In terms of the data, first of all, global mean basal rotation is higher in preschool age than in school age children (-6.30 ± 3.0 vs -4.40 ± 2.3, $p < 0.05$). For observation of six segments at short axis images, anteroseptal, anterior, lateral, and posterior segments demonstrated some trend of higher rotation in preschool than in school age children (-3.61 ± 2.5 vs -2.64 ± 2.2, -4.40 ± 2.4 vs -3.41 ± 3.4, -6.51 ± 2.8 vs -5.62 ± 3.3, -7.67 ± 4.0 vs -5.94 ± 3.6, p = ns), and inferior and septal segments brought statistically significant higher rotation in preschool than in school age children (-9.21 ± 3.5 vs -6.55 ± 3.0, -8.03 ± 3.1 vs -5.23 ± 3.6, $p<0.02$) (Table 1).

Although there was no statistical significance, global mean apical rotation is also higher in preschool age than in school age children (7.68 ± 5.1 vs 6.83 ± 7.0, p = ns). For the same six segments at short axis images, apical rotation data were all higher in preschool than in school age children at anteroseptal, anterior, lateral, posterior, inferior, and septal segments (9.46 ± 4.5 vs 8.02 ± 6.2, 9.60 ± 5.1 vs 8.07 ± 6.2, 9.12 ± 5.6 vs 7.36 ± 7.6, 8.24 ± 5.3 vs 6.46 ± 7.9, 6.55 ± 5.5 vs 6.10 ± 7.3, 8.41 ± 4.0 vs 7.24 ± 7.0, p = ns) (Table 1).

Table 1. Rotation data comparison with speckle tracking echocardiography at basal and apical view between preschool and school age children

Basal Rotation	mean	AntSept	Ant	Lat	Post	Inf	Sept
Preschool age	-6.3±3.0	-3.6±2.5	-4.4±2.4	-6.5±2.8	-7.7±4.0	-9.2±3.5	-8.0±3.1
School age	-4.4±2.3	-2.6±2.2	-3.4±3.4	-5.6±3.3	-5.9±3.6	-6.6±3.0	-5.3±3.6
p-value	0.05	ns	ns	ns	ns	0.02	0.02
Apical Rotation	**mean**	**AntSept**	**Ant**	**Lat**	**Post**	**Inf**	**Sept**
Preschool age	7.7±5.1	9.5±4.5	9.6±5.1	9.1±5.6	8.2±5.3	6.6±5.5	8.4±4.0
School age	6.8±7.0	8.0±6.2	8.1±6.6	7.7±7.6	6.5±7.9	6.1±7.3	7.2±7.0
p-value	ns	ns	ns	ns	ns	ns	ns

Radial Strain and Circumferential Strain with speckle tracking echocardiography

Basal radial strain was not different at each segment (31.5 ± 11.7 vs 36.5 ± 18.6, 40.3 ± 17.2 vs 44.1 ± 19.8, 54.1 ± 15.2 vs 50.2 ± 20.5, 58.7 ± 18.0 vs 52.4 ± 23.7, 53.3 ± 20.5 vs 47.2 ± 24.4, 39.8 ± 18.3 vs 32.2 ± 21.9, p = ns). Apical radial strain was not different, but showed higher trend in preschool age children than school age children, especially greater at anterior, lateral, and posterior segments (52.8 ± 17.4 vs 34.7 ± 23.2, 55.8 ± 20.4 vs 36.1 ± 22.7, 57.1 ± 17.6 vs 38.5 ± 21.7, $p<0.02$) (Table 2).

Table 2. Radial Strain data comparison with speckle tracking echocardiography at basal and apical view between preschool and school age children

Basal Radial Strain	**AntSept**	**Ant**	**Lat**	**Post**	**Inf**	**Sept**
Preschool age	**31.5±11.7**	**40.3±17.2**	**54.1±15.2**	**58.7±18.0**	**53.3±20.5**	**39.8±18.3**
School age	**36.5±18.6**	**44.1±19.8**	**50.2±20.5**	**52.4±23.7**	**47.2±24.4**	**32.2±21.9**
p-value	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
Apical Radial Strain	**AntSept**	**Ant**	**Lat**	**Post**	**Inf**	**Sept**
Preschool age	**45.9±20.9**	**52.8±17.4**	**55.8±20.4**	**57.1±17.6**	**52.6±17.2**	**38.3±21.1**
School age	**35.7±24.3**	**34.7±23.2**	**36.1±22.7**	**38.5±21.7**	**41.7±21.6**	**37.7±20.6**
p-value	**ns**	**0.02**	**0.02**	**0.01**	**ns**	**ns**

Meanwhile, basal circumferential strain was not statistically different at each segment (-26.7 ± 6.7 vs -25.7 ± 8.2, -13.9 ± 6.8 vs -16.6 ± 5.7, -17.4 ± 8.2 vs -14.7 ± 5.7, -18.3 ± 9.0 vs -17.0 ± 6.3, -20.6 ± 8.0 vs -21.5 ± 7.2, -29.1 ± 6.2 vs -25.9 ± 8.0, p = ns). Apical circumferential strain did not demonstrate statistical difference (-24.9 ± 4.7 vs -25.5 ± 7.7, -20.4 ± 6.8 vs -20.8 ± 9.6, -17.9 ± 7.2 vs -18.4 ± 6.6, -16.7 ± 6.4 vs -18.4 ± 7.0, -19.8 ± 4.3 vs -21.0 ± 7.6, -23.1 ± 9.0 vs -25.3 ± 7.8, p = ns) (Table 3).

Table 3. Circumferential Strain data comparison with speckle tracking echocardiography at basal and apical view between preschool and school age children

Basal Circumferential Strain	AntSept	Ant	Lat	Post	Inf	Sept
Preschool age	-26.7±6.7	-13.9±6.8	-17.4±8.2	-18.3±9.0	-24.6±5.4	-29.1±6.2
School age	-25.7±8.2	-16.6±5.7	-14.7±5.7	-17.0±6.3	-21.5±7.2	-25.9±8.0
p-value	ns	ns	ns	ns	ns	ns
Apical Circumferential Strain	**AntSept**	**Ant**	**Lat**	**Post**	**Inf**	**Sept**
Preschool age	-24.9±4.7	-20.4±6.8	-17.9±7.2	-16.7±6.4	-19.8±4.3	-23.1±9.0
School age	-25.5±7.7	-20.8±9.6	-18.4±6.6	-18.4±7.0	-21.0±7.6	-25.3±7.8
p-value	ns	ns	ns	ns	ns	ns

LV Torsion pattern

According to these basal and apical rotation data, LV torsion is greater in preschool age children than school age children (12.6 ± 5.8 vs 9.5 ± 6.9) without statistically significant (p = ns) (Table 4).

Table 4. Torsion data comparison from basal and apical rotation data with speckle tracking echocardiography between preschool and school age children

Torsion	mean	AntSept	Ant	Lat	Post	Inf	Sept
Preschool age	**12.6±5.8**	**9.9±7.1**	**11.0±7.6**	**12.0±8.8**	**13.1±8.4**	**13.0±7.1**	**13.0±6.5**
School age	**9.5±6.9**	**9.0±7.0**	**9.7±7.2**	**10.9±7.5**	**10.8±6.9**	**11.0±6.8**	**10.8±8.1**
p-value	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**

IV. DISCUSSION

Modulation of LV torsion appears to reflect both myocardial mechanical maturation in childhood, influenced by contractility, loading conditions, and possible myogenetic changes through growth life.

In this study, all enrolled forty (2 to 14 year-old) children did not show statistical difference of LV ejection fraction and LV posterior wall thickness index. However, basal and apical rotation data of preschool age children were higher than those of school age children. From these rotation data, calculated LV torsion was higher in preschool age children than school age children. This result implies that contractility is higher in younger preschool age children compared with older school age children. As published by Notomi, LV torsion was higher in infants (n=9, 9 ± 11 mo, < 2 yr) than in older children (n=8, 7 ± 3 yr), adolescents (n=8, 16 ± 2 yr), and young adults (n=10, 28 ± 3 yr),[24] which is correlated with the finding that contractility is higher in children under 2 years of age due to higher metabolic demand compared with older children.[33] Although we did not include infants in this study, it is possible that younger preschool age children demonstrated higher torsion from the similar reason of infants. It is well known that the right ventricles of newborn infants are hypertrophied compared with those of older school age children and adults owing to the systemic pressure and resistance of the right ventricle. Infants and younger children have relative LV hypertrophy as well, as previously presented by Harada.[34] This hypertrophy recedes with a concomitant change in fiber architecture for aging, which may affect ventricular rotation. Interestingly, the trend of greater rotation of preschool children at base and apex, resulted in higher torsion as well in this study, even though it is not statistically significant.

This is the first study to measure rotation and short axis radial and circumferential direction strain together at base and apex, to observe how these parameters interact. Strain measure for myocardial deformation in radial and circumferential direction showed no statistical difference at the base with aging, which was well correlated with the report that LV geometry and systolic ejection fraction were constant from infancy to adulthood with aging.[33, 35] However, there was noticeable higher strain at the very inferior and septal segments with radial and circumferential direction despite without statistical difference (Table 2 - 3), which would affect the rotation to be greater at inferior and septal segments in younger preschool age children (Table 1). Therefore, at base level, the radial and circumferential myocardial deformation may affect together LV rotation and torsion.

Meanwhile, the apical radial strain at anterior, lateral, and posterior segments were significantly higher in preschool age children (Table 2), however, apical circumferential strain did not show the difference at anteroseptal, anterior, lateral, posterior, inferior, and septal segments of short axis (Table 3). Thus the apical rotation without significant difference at each short axis segment even though preschool age children showed the higher rotation, might be affected much more by circumferential deformation rather than radial deformation (Table 1). The impact of apical circumferential strain to be greater than radial deformation is intriguing for apical rotation and torsion. At apex, circumferential myocardial deformation might be more important for myocardial performance.

We observed that the rotation did not change much during childhood between 2 to 14 years old, while aging-related decrease trend in LV torsion for the childhood period resulted from a subtle change in radial and circumferential strain of basal and apical myocardial segmental deformation.

In terms of future clinical impact, having normal control reference values for children’s LV torsion, could be useful to assess various myocardial disease statuses. LV torsion is certainly a sensitive index of cardiac performance, which may benefit for better understanding of cardiomyopathy, hypertensive myocardium, postoperative congenital heart disease myocardium, and other myocardial changes. Furthermore, this systolic torsion study might explore a new viewpoint as a mechanistic manifestation of the diastolic characteristics for growth in childhood.

V. CONCLUSIONS

In conclusion, we found that there was some trend of decrease rotation and torsion value in aging during childhood from 2 to 14 years old. Although there was no statistically significant age-related change in LV torsion from rotation data, the further investigation should be continued.

REFERENCES

1. Buckberg GD, Weisfeldt MI, Ballester M, et al. Left ventricular form and function: Scientific priorities and strategic planning for development of new views of disease. Circulation 2004; 110:e333 – 6
2. Notomi Y, Lysyansky P, Setser RM, Shiota T, Popovic ZB, Weaver JA, Oryszak SJ, Greenberg NL, White RD, Thomas JD. Measurement of ventricular torsion by two-dimensional ultrasound speckle tracking imaging. J Am Coll Cardiol 2005; 45: 2034 – 41.
3. McDonald IG. The shape and movements of the human left ventricular during systole: a study by cineangiography and by cineradiography of epicardial markers. Am J Cardiol 1970; 26: 221 – 30.
4. Rademakers FE, Buchalter MB, Rogers WJ, Zerhouni EA, Weisfeldt MI, Weiss JL, Shapiro EP. Dissociation between left ventricular untwisting and filling: accentuation by catecholamines. Circulation 1992; 85: 1572 – 81.
5. Gibbons Krocker CA, Ter Keurs HE, Knudtson ML, Tyberg JV, Beyar R. An optical device to measure the dynamics of apex rotation of the left ventricle. Am J Physiol Heart Circ Physiol 1993; 265: H1444 -9.
6. Moon MR, Ingels NB, Daughters GT, Stinson EB, Hansen DE, Miller DC. Alterations in left ventricular twist mechanics with inotropic stimulation and volume loading in human subjects. Circulation 1994; 89: 142 – 50.

7. Hansen DE, Daughters GT, Alderman EL, Ingels NB, Stinson EB, Miller DC. Effect of volume loading, pressure loading, an inotropic stimulation on left ventricular torsion in humans. Circulation 1991; 83: 1315 – 26.
8. Yun KI, Niczyporuk MA, Daughters GT, Ingels NB, Stinson EB, Alderman EL, Hansen DE, Miller DC. Alterations in left ventricular diastolic twist mechanics during acute human cardiac allograft rejection. Circulation 1991; 83: 962 – 73.
9. Maiser SE, Fischer SE, McKinnon GC, Hess OM, Krayenbuchl HP, Boesiger P, Evaluation of left ventricular segmental wall motion in hypertrophic cardiomyopathy with myocardial tagging. Circulation 1992; 86: 1919 – 28.
10. Buchalter MB, Rademakers FE, Weiss JL, Rogers WJ, Weisfeldt MI, Shapiro EP. Rotational deformation of the canine left ventricle measured by magnetic resonance tagging: effects of catecholamines, ischemia, and pacing. Cardiovasc Res 1994; 28: 629 – 35.
11. DeAnda A, Komeda M, Nikolic SD, Daughters GT, Ingels NB, Miller DC. Left ventricular function, twist, and recoil after mitral valve replacement. Circulation 1995; 92: 458 – 66.
12. Gibbons Krocker CA, Tyberg JV, Beyar R. Effects of load manipulations, heart rate, and contractility on left ventricular apical rotation : an experimental study in anesthetized dogs. Circulation 1995; 92: 130 – 41.
13. Gibbons Krocker CA, Tyberg JV, Beyar R. Effects of ischemia on left ventricular apex rotation: an experimental study in anesthetized dogs.

Circulation 1995; 92: 3539 – 48.

14. Knudtson MI, Galbraith PD, Hildebrand KL, Tyberg JV, Beyar R. Dynamics of left ventricular apex rotation during angioplasty: a sensitive index of ischemic dysfunction. Circulation 1997; 96: 801 – 8.

15. Stuber M, Scheidegger MB, Fischer SE, Nagel E, Steinemann F, Hess OM, Boesiger P. Alterations in the local myocardial motion pattern in patients suffering from pressure overload due to aortic stenosis. Circulation 1999; 100: 361 – 8.

16. Nagel E, Stuber M, Lakatos M, Scheidegger MB, Boesiger P, Hess OM. Cardiac rotation and relaxation after anterolateral myocardial infarction. Coron Artery Dis 2000; 11: 261 – 7.

17. Sandstede JW, Johnson T, Harre K, Beer M, Hofmann S, Pabst T, Kenn W, Voelker W, Neubauer S, Hahn D. Cardiac systolic rotation and contraction before and after valve replacement for aortic stenosis: a myocardial tagging study using MR imaging. Am J Roentgenol 2002; 178: 953 – 8.

18. Fuchs E, Muller MF, Oswald H, Thony H, Mohasci P, Hess OM. Cardiac rotation and relaxation in patients with chronic heart failure. Eur J Heart Failure 2004; 6: 715 – 22.

19. Tibayan FA, Rodriguez F, Langer F, Zasio MK, Bailey L, Liang D, Daughters GT, Ingels NB, Miller DC. Alterations in left ventricular torsion and diastolic recoil after myocardial infarction with and without chronic ischemic mitral

regurgitation. Circulation 2004; 110(suppl II): II 109 – II 114.

20. Wagner R, Smith S, Sandrik J, Lopez II. Statistics of speckle in ultrasound B-scans. IEEE Trans Sonics Ultrasonics 1983; 30: 156 – 63

21. Bohs LN, Trahey GE. A novel method for angle independent ultrasonic imaging of blood flow and tissue motion. IEEE Trans Biomed Eng 1991; 38: 280 – 6.

22. Meunier J, Bertrand M. Ultrasonic texture motion analysis: theory and simulation. IEEE Trans Med Imaging 1995; 14: 293 – 300.

23. Suhling M, Jansen C, Arigovindan M, Buser P, Marsch S, Unser M, Hunziker P. Multiscale motion mapping; a novel computer vision technique for quantitative, objective echocardiographic motion measurement independent of Doppler; first clinical description and validation. Circulation 2004; 110: 3093 – 9.

24. Notomi Y, Srinath G, Shiota T, Martin-Miklovic MG, Beachler L, Howell K, Oryszak SJ, Deserranno DG, Freed AD, Greenberg NL, Younoszai A, Thomas JD. Maturational and adaptive modulation of left ventricular torsional biomechanics: Doppler tissue imaging observation from infancy to adulthood. Circulation 2006; 113: 2534 – 41.

25. Stopfkuchen H. Changes of the cardiovascular system during the perinatal period. Eur J Pediatr 1987; 146: 545 – 9.

26. Wulfsohn D, Nyengaard JR, Tang Y. Postnatal growth of cardiomyocytes in the left ventricle of the rat. Anat Rec 2004; 277A: 236 – 47.

27. Siedner S, Kruger M, Schroeter M, Metzler D, Roell W, Fleischmann BK,

Hescheler J, Pfitzer G, Stehle R. Developmental changes in contractility and sarcoplasmic proteins from the early embryonic to the adult stage in the mouse heart. J Physiol 2003; 548: 493 – 505.

28. Lahmers S, Wu Y, Call DR, Labeit S, Granzier H. Developmental control of titin isoform expression and passive stiffness in fetal and neonatal myocardium. Circ Res 2004; 94: 515 – 13.

29. Senzaki H, Akagi M, Hishi T, Ishizawa A, Yanagisawa M, Masutani S, Kobayashi T, Awa S. Age-associated changes in arterial elastic properties in children. Eur J Pediatr 2002; 161: 547 – 51.

30. Oxenham H, Sharpe N. Cardiovascular aging and heart failure. Eur J Heart Fail 2003; 5: 427 – 34.

31. Setser RM, Kasper JM, Lieber ML, Starling RC, McCarthy PM, White RD. Persistent abnormal left ventricular systolic torsion in dilated cardiomyopathy after partial left ventriculectomy. J Thorac Cardiovasc Surg 2003; 126: 48 -55.

32. Notomi Y, Setser RM, Shiota T, Martin-Miklovic MG, Weaver JA, Popovic JB, Yamada H, Greenberg NL, White RD, Thomas JD. Assessment of left ventricular study with tagged magnetic resonance imaging. Circulation 2005; 111: 1141 – 7.

33. Colan SD, Parness IA, Spevak PJ, Sanders SP. Developmental modulation of myocardial mechanics: age- and growth-related alterations in afterload and contractility. J Am Coll Cardiol 1992; 19: 619 – 29.

34. Harada K, Suzuki T, Shimada K, Takada G. Role of left ventricular mass/volume ratio on transmitral flow velocity patterns from infancy to childhood. Int J Cardiol 1998; 63: 9 – 14.

35. Nidorf SM, Picard MH, Triulzi MO, Newell J, King ME, Weyman AE. New perspectives in the assessment of cardiac chamber dimensions during development and adulthood. J Am Coll Cardiol 1992; 19: 983 – 8.

국문 요약 **(In Korean)**

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본 연구는 소아의 연령 변화에 따른 좌심실 회전 및 심실 비틀림을 관찰한 연구이다. 현재까지 보고에 의하면 심실 비틀림은 나이에 따라 의미 있는 변화를 보이지는 않는다고 알려져 왔다. 그러나 어린이 연령에서 학동기 전 후 나이에 따른 좌심실 회전과 비틀림의 관계에 대해서는 알려진 바가 거의 없다.

40명의 소아 중 학동기 전 어린이 20명 (2세 – 6세), 학동기 어린이 20명 (7세 – 12세)을 대상으로 하였고, 심초음파 단축 영상에서 심장 기저부와 심첨부를 각각 심근벽 구획에 따라 분리 분석하였다. 좌심실 회전 및 비틀림 양상은 심장 기저부와 심첨부에서 통계적 유의성은 없었으나 학동기 전 어린이 보다 학동기 어린이에서 감소하는 경향을 나타내었다. 즉 학동기 전 어린이에서 더 큰 심실 회전과 비틀림을 나타내는 경향을 보였다.

소아의 심근증을 비롯한 기타 심장질환 평가 및 치료에 기여하고자 좌심실 회전 및 심실 비틀림 현상을 연령 변화에 따라 관찰하였으며, 향후 지속적인 연구가 필요할 것이다.

핵심되는 말 : 어린이: 좌심실 회전: 심실 비틀림: 연령 변화