Speckle tracking based myocardial velocities: our experience with novel software

Benek izleme temelli miyokardiyal hızlar: Yeni bir yazılım ile olan deneyimlerimiz

Oben Baysan, Mesut Akyol, Barış Bugan, Mehmet Yokuşoğlu, Yalçın Gökoğlan, Celal Genç*

From Departments of Cardiology and *Biostatistics, Gülhane Military Medical School, Ankara, Turkey

Abstract

Objective: Speckle tracking is a new imaging modality capable of providing information about myocardial motion in all three directions: longitudinal, circumferential and radial. There are many software packages with their unique tracking algorithms and user interfaces in the market. We aimed to evaluate the feasibility of QLAB software in clinical practice and speckle based myocardial velocities in healthy subjects.
Methods: Thirty-two subjects were enrolled in the study. Images from apical four-chamber, apical two-chamber, parasternal short-axis (mitral valve-apical levels) views were acquired and analyzed offline with QLAB. We measured speed and velocity data in longitudinal, circumferential and radial directions. Time percent of these events were also calculated. In the final data analysis 825 of 832 segments (99.2%) were included. Mann Whitney U, Student's t and Kendall's tau-b coefficient tests were used for statistical analysis.
Results: We determined that circumferential speed was significantly higher ($p<0.001$) than radial velocity in both parasternal short-axis views. Likewise, longitudinal speed was higher ($p<0.001$) than radial velocity in apical views. Notwithstanding the speed and velocity data, time percent of radial velocity were significantly lower ($p<0.001$ for all) than their longitudinal or circumferential counterparts. We also notified that apex was the segment reaching its maximum speed at earliest time. QLAB measurement time was relatively long (8.1±1.7 min) and intraobserver agreement was lost in 3% of the segments.
Conclusion: In addition to these findings, we consider QLAB software package for speckle tracking needs some improvements to shorten measurement time and decrease user intervention. *(Anadolu Kardiyol Derg 2010; 10: 233-8)*
Key words: Speckle tracking, QLAB software, myocardial velocities

Özet

Amaç: Benek izleme (speckle tracking), miyokart hareketinin tüm yönleri hakkında (longitüdinal, sirkümferansiyal ve radiyal) bilgi veren yeni bir görüntüleme yöntemidir. Bu amaçla kendi takip algoritmaları ve kullanıcı arabirimlerine sahip birçok yazılım piyasaya sunulmuştur. Biz bu çalışmada, QLAB yazılımının klinik uygulamada kullanılabilirliğini ve sağlıklı bireylerde miyokart hızlarını benek izleme yöntemiyle değerlendirmeyi amaçladık.
Yöntemler: Çalışmaya 32 sağlıklı birey dahil edildi. Apikal 4 oda, apikal 2 oda ve parasternal kısa eksen (mitral kapak ve papiller kas seviyesi) görüntüleri her bireyde alınarak QLAB yazılımıyla incelendi. Longitüdinal, sirkümferansiyal ve radiyal yöndeki hız ve vektöriyel hız verileri ölçüldü. Bu olayların gerçekleştiği zaman, yüzde olarak hesaplandı. Görüntülenmeye çalışılan 832 segmentten 825'i (%99.2) değerlendirmeye alındı. İstatistiksel analizde Mann Whitney U, Student t ve Kendall's tau-b katsayısı testleri kullanıldı.
Bulgular: Sirkümferansiyal hız her iki parasternal kısa eksen kesitlerinde de radiyal hız vektöründen daha fazlaydı ($p<0.001$). Benzer olarak longitüdinal hız radiyal hız vektöründen apikal kesitlerde daha fazlaydı($p<0.001$). Bununla birlikte radiyal hız vektörünün en üst seviyeye çıkma zamanı longitüdinal ve sirkümferansiyal yöndeki radiyal hız vektörünün oluşma zamanından daha kısaydı ($p<0.001$). Biz ayrıca apeksin en erken maksimum hıza ulaşan segment olduğunu saptadık. QLAB ölçüm zamanı nispeten uzundu (8.1±1.7 dakika) ve gözlemci içi uyum değerlendirilen segmentlerin %3'ünde bulunmamaktaydı.
Sonuç: Bu bulgulara ek olarak, QLAB yazılımının ölçüm süresini kısaltan ve kullanıcı müdahalesini azaltan bazı düzeltmelere ihtiyaç duyulduğu sonucuna vardık. *(Anadolu Kardiyol Derg 2010; 10: 233-8)*
Anahtar kelimeler: Benek izleme, QLAB yazılımı, miyokardiyal hızlar

Address for Correspondence/Yazışma Adresi: Dr. Mehmet Yokuşoğlu, Gülhane Military Medical School, Department of Cardiology Gn. Tevfik Sağlam Cad. 06018, Etlik, Ankara, Turkey Phone: + 90 312 304 42 67 Fax: +90 312 304 42 50 E-mail: myokusoglu@yahoo.com
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Introduction

Speckle tracking of two-dimensional images is a new technique for measuring myocardial deformation and velocity. The information provided by speckle tracking has been mainly based on strain or strain rate data and has increased our knowledge on left ventricular dyssynchrony, left ventricular rotation dynamics such as twisting or untwisting and right ventricular functions. Myocardial velocities can be measured echocardiographically with either tissue Doppler-based or speckle tracking methods. Myocardial velocity determination is used to assess systolic and diastolic functions in various disease states including coronary artery disease (1), myocardial infarction (2) and hypertrophic cardiomyopathy (3). However, tissue Doppler-based technique has its own well-known limitations, such as angle dependency. Conversely, speckle tracking is an angle independent technique and may provide incremental data about myocardial velocities by measuring velocities in segments not suitable for tissue Doppler imaging. Although there are a few commercially available software packages for speckle tracking with their unique algorithms and user interfaces, little is known about usefulness and limitations of these softwares in the daily clinical practice and normal segmental myocardial velocities measured with this method.

We aimed in this study to determine the usefulness of QLAB software (version 6.0) in clinical practice by measuring left ventricular myocardial velocities in apical and short-axis views in healthy subjects.

Methods

After providing informed consent form, thirty-two healthy volunteers were included in the study. The study protocol was reviewed and approved by the local Ethics committee.

Normal vital sign measurements, physical examination, routine blood chemistry analyses were accepted as satisfactory for confirming healthy status. We performed transthoracic echocardiographic examinations in all subjects at rest in the left lateral decubitus position with a Philips I33 machine (Philips, Best, Netherlands) equipped with broadband S5-1 transducer. Grayscale images in parasternal long-axis, parasternal short-axis at mitral and apical level, apical four-chamber (4ch) and apical two- chamber (2ch) views were recorded on hard disk. Pulse-wave Doppler was used at left ventricular outflow tract for calculation of aortic valve opening and closing times. Three consecutive end-expiratory cycles in each echocardiographic view with frame rate ranging from 50 Hz to 70 Hz were acquired and transferred to DVD media for offline analyses.

Data analysis

QLAB software (Phillips, Andover, Massachusetts, USA) with advanced tissue motion quantification module (TMQA) installed on a personal computer was used for data analysis. QLAB software options were set as default, which included at least six segment analyses for each view. We began with short-axis images at the mitral valve level on which region of interest circle was putted on outer contour of myocardial border (Fig. 1). Then, tissue- tracking button was activated and septal orientation was marked (Fig. 2). The software has options for increasing tracking points, myocardial endocardial and epicardial border penetration all of which manually and visually arranged. Thereafter, the software automatically analyzed target area according to six-segment model (Fig. 3) and the results were visually interpreted as sufficient or not. In case of visually determined insufficient tracking, the borders of relevant segments were manually corrected on frame-by- frame basis and automatic tracking repeated until satisfactory tracking results were achieved. We applied same measurement principles to apical short axis images. For apical 4- and 2-chamber views the analysis was started with selection of three target points within the left ventricle (Fig. 4 and Fig. 5). The rest of the operation was as in the short-axis views, which included setting tracking borders, automatic calculation and manual correction as needed.

From each view, the results were exported to Excel spreadsheet program (Excel 2003, Microsoft Corporation, Redmond, Washington, The U.S.) from which maximum speed, peak positive velocity and peak negative velocity were calculated via Excel macros prepared by one of the authors (O.B). Furthermore, ave-

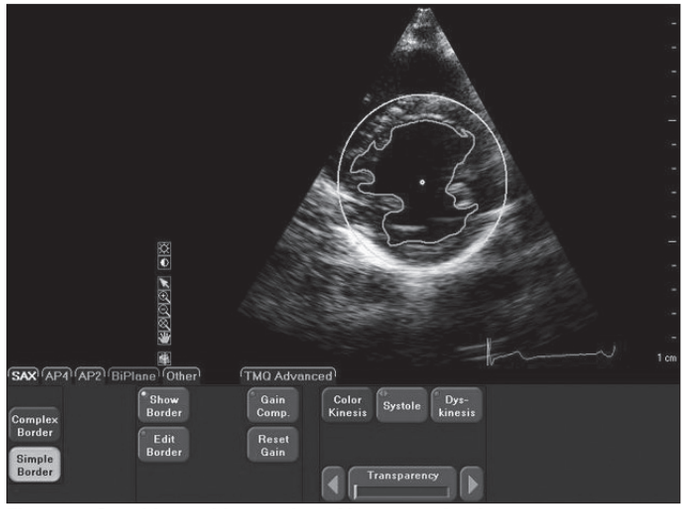

Figure 1. Speckle tracking: region of interest selection

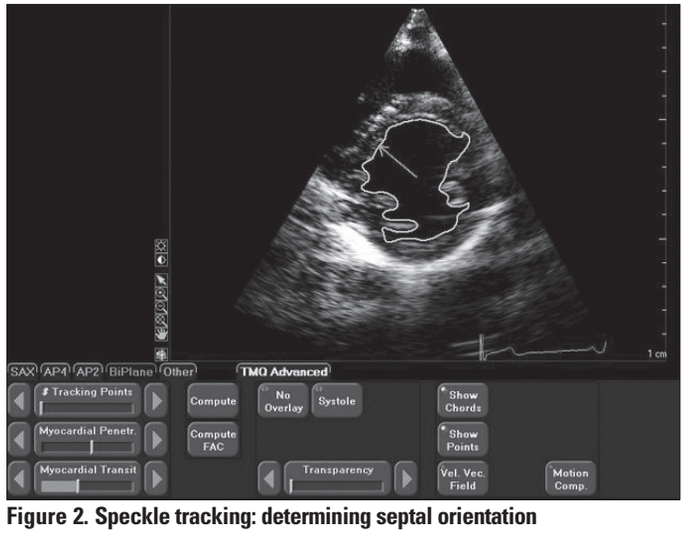

Figure 2. Speckle tracking: determining septal orientation

rage values for each calculated parameter was determined in same Excel spreadsheet from all segments in the view. Speed and velocity terms point to different definitions. Velocity is speed of a movement dictating a direction, therefore, is a vector. However, speed contains data about the speed of movement of the kernel regardless of where it is moving. Both of these definitions are represented by same unit: cm/sec.

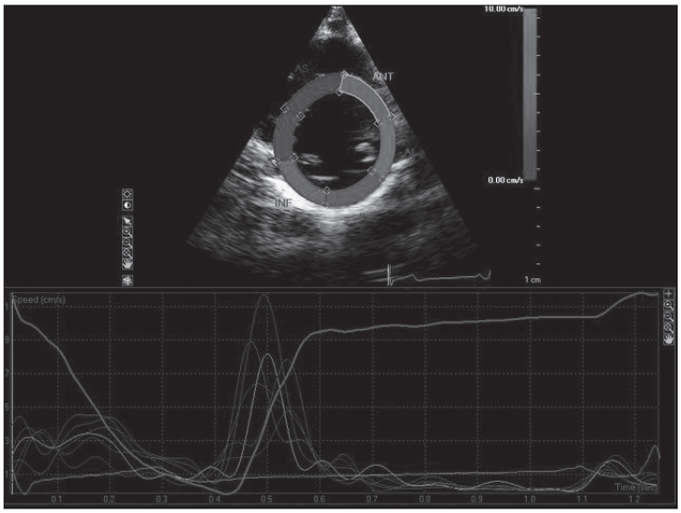

Figure 3. Short-axis results panel

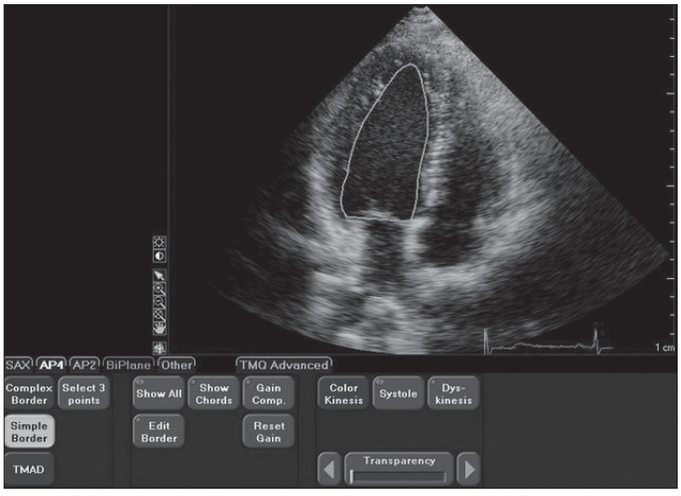

Figure 4. Speckle tracking: selecting 3 points for apical 4-chamber view

Exported results also included cycle length automatically determined by the software, which was used for time interval calculation of events as percents. Measurement times for QLAB and Excel spreadsheet were separately recorded. Same images, which were used in the first evaluation from randomly selected ten patients were reevaluated within two weeks by the same author for intraobserver differences.

Statistical analysis

We determined sample size as 32 by using G*Power software (Ver. 3.0.10, Franz Faul, Universität Keil, Germany) (effect size dz=0.45, power=0.80, α=0.05 type I error level and β=0.20). We used SPSS for Windows Version 15 software (SPSS Inc., Chicago, IL., USA) for statistical analyses. The distribution of data was tested with Shapiro-Wilks test. Descriptive statistics of the data are presented as mean±SD or median (interquartile range-IQR-) values. Average speed and velocity data from all segments in each view were compared with Student's t test (circumferential speed and radial velocity data for all image views) or Mann Whitney U test (speed and velocity time percent values for all image views) according to data distribution. Intraobserver agreement was measured by Kendall's tau-b concordance coefficient. A p value less than or equal 0.05 was accepted as statistically significant for all tests.

Results

In 32 subjects (mean age: 23±4 years, male/female ratio: 26/6) a total of 832 myocardial segments were analyzed. Manual correction was required in 33 segments (4%) and seven segments (0.8%) were excluded because of poor tracking quality even after manual correction. Therefore 99.2% of segments were included in the final analysis. Ejection fraction was within normal limits in all subjects (64±5%). Mean cycle length, aortic opening and closing times were 855.3±160.1, 82.3±15.4, and 358.3±34.2 msec, respectively.

Segmental short-axis circumferential speed and radial velocity data at the mitral valve and apical levels are presented in Table 1. Apical 4- and 2-chamber segmental data including longitudinal speed and radial velocity are given in Table 2. The means of average circumferential (short-axis) and longitudinal

Table 1. Short- axis myocardial speed, velocity and time percentage data for 32 healthy young volunteers

Parameters	Maximum Speed, cm/sec		Max Speed time, %		Radial Max. Velocity, cm/sec		Radial Max time, %		Radial Min. Velocity, cm/sec		Radial Min Velocity Time, %	
	Mitral	Apical	Mitral	Apical	Mitral	Apical	Mitral	Apical	Mitral	Apical	Mitral	Apical
Antero-septal	3.9 (1.7)	4.5±1.4	47.0 (46.0)	26.5 (46.8)	2.8±0.8	3.4±1.0	23.0 (31.5)	20.5 (9.8)	-3.6 (1.6)	-3.7 (1.9)	60.0 (11.75)	58.0 (9.8)
Anterior	4.6±2.0	4.3±1.9	42.0 (43.0)	28.0 (47.5)	3.2±1.5	2.7±1.3	17.0 (15.0)	22.0 (25.5)	-4.2 (2.4)	-4.0 (3.3)	54.0 (11.8)	53.5 (16.5)
Antero-lateral	5.6±2.2	4.5±1.8	47.5 (38.5)	49.0 (43.0)	3.8±1.6	3.1±1.5	16.0 (9.0)	20.0 (24.8)	-5.4±2.8	-4.2±1.5	54.0 (7.0)	52.0 (15.3)
Infero-lateral	5.9±1.8	4.9±1.9	51.5 (16.0)	49.0 (41.8)	4.0±1.0	3.2 (1.8)	17.0 (4.8)	16.5 (6.0)	-6.1±2.2	-4.6 (3.5)	53.5 (7.5)	54.0 (11.0)
Inferior	6.1±1.8	5.5±2.0	52.0 (13.3)	54.0 (41.0)	4.3±1.1	4.3 (2.0)	19.0 (8.0)	19.0 (5.8)	-6.4±2.0	-4.8 (2.8)	54.0 (11.3)	55.5 (8.8)
Infero-septal	5.3±1.4	5.2±1.5	54.0 (15.8)	52.0 (42.0)	3.3±1.0	4.2 (1.9)	19.0 (14.0)	19.2±6.4	-4.8±1.6	-5.2±1.6	55.0 (17.3)	55.5 (13.8)

The values are expressed as mean±standard deviation or median (interquartile range) values

Table 2. Apical 4-chamber and 2-chamber myocardial speed, velocity and time percentage data for 32 healthy young volunteers

Parameters	Maximum Speed, cm/sec		Maximum Speed Time, %		Radial Maximum Velocity, cm/sec		Radial Maximum Velocity Time, %		Radial Minimum Velocity, cm/sec		Radial Minimum Velocity Time, %	
	Ap4ch	Ap2ch	Ap4ch	Ap2ch	Ap4ch	Ap2ch	Ap4ch	Ap2ch	Ap4ch	Ap2ch	Ap4ch	Ap2ch
Basal Septum &Inferior	9.3±1.8	10.3±2.4	53.0 (14.8)	54.0 (10.0)	2.9±1.2	3.1±0.9	20.5 (35.3)	17.0 (8.0)	-3.1 (2.1)	-4.1±1.3	59.0 (18.0)	55.2±6.6
Mid Septum &Inferior	7.3±1.5	7.8±1.9	53.0 (14.3)	54.0 (9.0)	3.5 (1.3)	4.1±1.0	20.0 (7.5)	19.0 (7.0)	-5.0 (1.7)	-5.7±1.8	57.5 (15.0)	55.3±7.0
Apical Septum &Inferior	4.2 (1.2)	5.1±1.3	46.6±23.4	26.0 (34.0)	2.3±0.4	3.3±1.0	19.2±5.7	21.0±3.6	-2.8 (1.3)	-3.5 (1.4)	54.0 (13.5)	56.2±6.9
Apex	2.7±1.0	2.8±1.0	26.0 (38.5)	22.0 (14.0)	2.1 (0.6)	2.1±0.6	16.3 ± 5.0	17.0±5.4	-3.6±1.2	-3.4±1.0	51.0 (12.5)	54.0 (11.0)
Apical Lateral &Anterior	7.2±2.3	3.1 (3.3)	40.0 (41.0)	39.0 (47.0)	2.4±0.8	2.1 (1.5)	17.5 (13.8)	19.9±9.1	-4.0±1.7	-3.1 (1.4)	51.5 (11.0)	53.0 (13.0)
Mid Lateral &Anterior	7.9±2.8	7.6±3.5	51.0 (35.3)	51.0 (46.0)	3.6±1.1	3.2 (1.7)	11.5 (11.0)	17.0 (21.0)	-5.9±2.6	-4.4 (2.3)	51.0 (15.5)	52.0 (12.0)
Basal Lateral &Anterior	5.0±1.8	7.2±2.0	52.0 (10.0)	53.0 (10.0)	2.5±0.5	2.8±0.5	19.5 (6.8)	20.0 (5.0)	-3.3±0.9	-4.0 (1.6)	54.6±8.4	54.6±6.2

The values are expressed as mean ± standard deviation or median (interquartile range) values
Ap4ch - apical 4-chamber, Ap2ch - apical 2-chamber

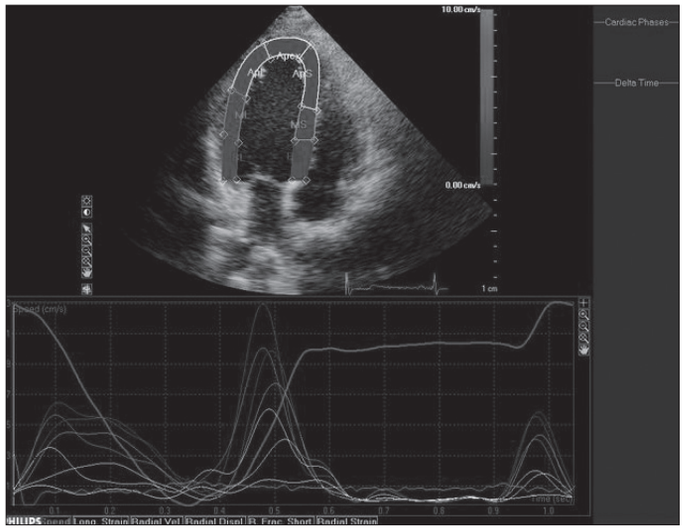

Figure 5. Apical results panel

speed (apical views) were significantly higher ($p<0.001$) than the mean of average radial velocity in both short axis and apical views (Fig. 6). Time percents of circumferential and longitudinal speed were also significantly longer ($p<0.001$) compared to time percent of radial velocity in short-axis and apical views (Fig. 7).

While QLAB measurement time was 8.1±1.7 min, data analysis with Excel program required more time (22.6±4.3 min). Mean intra-observer agreement (Kendall's tau-b) for velocity and speed was 0.63±0.10 (τ_b range: 0.51-0.89) and 0.69±0.19 ((τ_b range: 0.52-0.94), respectively. We did not detect significant Kendall's tau-b concordance coefficient in 8 of 260 (3%) segments for velocity and speed measurements (Short-axis velocity measurements: anteroseptal segment; Apical views velocity measurements: inferoapical segment and basal septal segment; Short-axis speed measurements: anterior, anteroseptal and anterolateral segments; Apical views speed measurements: mid and basal lateral segments).

Discussion

In our study, we quantified left ventricular segmental radial, circumferential and longitudinal velocity and speed in healthy subjects with aid of QLAB software.

Myocardial velocity determination has been used successfully for systolic or diastolic function evaluation (4). Both color Doppler or pulse- wave Doppler can be used for this purpose (5). Unfortunately, tissue Doppler is an angle dependent technique, which restricts its use in evaluation of myocardial movement in radial or circumferential direction. In contrast, two- dimensional speckle imaging allows myocardial velocity determination independent of insonation angle (6, 7). Although we did not try to delineate segmental speed, velocity and time percent differences because of very big segment number to be compared, we notified in our study results that myocardial speed in longitudinal direction decreased in base to apex orientation as previously reported with tissue Doppler imaging (8, 9). We also determined that apex was the earliest site, which reached its maximum speed in longitudinal axis. This finding is in accordance with traditional view stated that left ventricular contraction has apex to base gradient (10). Unfortunately, more recent findings as reviewed by Buckberg et al. (11) suggested reverse left ventricular contraction gradient (base to apex). We did not directly measure segmental activation times directly and different acceleration rates within left ventricle may cause apex to reach its maximum speed quickly.

Our study results implied that radial velocity timing was earlier than circumferential or longitudinal speed. Buckberg et al. (11) explained normal left ventricular mechanical sequences as follows: narrowing, shortening, lengthening and widening. Therefore, we can assume that radial contraction precedes longitudinal or circumferential motion (12).

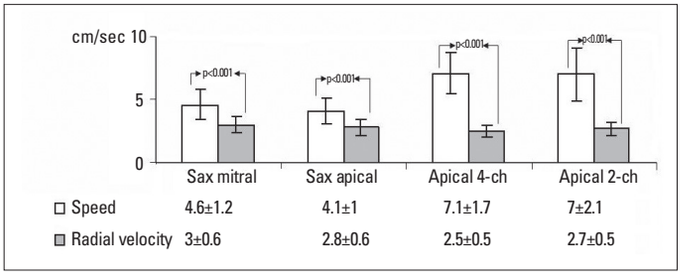

Figure 6. Speed and velocity data
2-ch - 2-chamber, 4-ch - 4-chamber

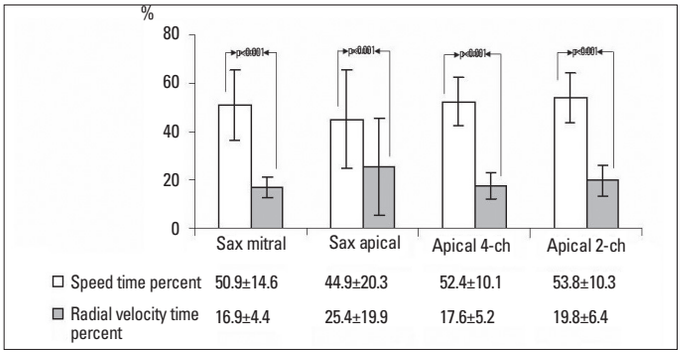

Figure 7. Time percentage data for speed and velocity
2-ch - 2-chamber, 4-ch - 4-chamber

QLAB software provided speed and velocity data in all patients. Though the terms speed and velocity used in daily practice interchangeably, they are actually different terms. While velocity is a vector physical quantity and speed is magnitude of velocity (13). We have no information about why vendor uses speed instead of velocity in their software. Furthermore, speckle tracking-based speed or velocity data is not comparable to values obtained with tissue Doppler imaging (14), which necessitates determination of normal or abnormal velocity or speed values for speckle tracking as in tissue Doppler imaging. Another important aspect of speckle derived speed or velocity determination is segmental variation of data, which necessitates the use of site-specific normal ranges as recommended by Marvick et al. (15). Although our study had no enough power to establish normal values, we thought that our results might be used for comparisons in further studies. Intraobserver agreement was lost in 3% of reevaluated 260 segments, which may be a good point for the software. Unfortunately, moderate size intraobserver agreement according to Kendall's tau-b test may limit clinical applicability of speckle derived velocity data.

Using QLAB requires initial training and experience obtained with frequent measurements. The absence of any comparison of interobserver reliability is the main obstacle because only one echocardiographer has training on QLAB use in our laboratory. Although other frequently used software package (EchoPAC, GE Vingmed Ultrasound AS, Horten, Norway) is capable of automatically exclude segments with poor tracking quality, QLAB does not provide such an opportunity (16). We thought that the presence of tracking validation might have been better option for minimizing user intervention. Relatively long measurement time with QLAB (8.1±1.7 min) also highlighted the requirement for software making quick automatic tracking with user- friendly interface according to our opinion. Indeed, recent version of QLAB (version 7.0) is hoped to decrease offline analysis time very significantly. Another problem we encountered with the software was apical segmentation. The software uses six-segment models in the apex but this is not in line with American Society of Echocardiography recommendations (17). We thought that apical segmentation should be corrected in future versions of the QLAB.

Study limitations

Quality of speckle tracking is directly related to image quality and we tried to overcome this restriction by selecting young and healthy subjects. As a result, our study population is not reflecting "real world" in which image quality may be a problem in some patients (18). In addition, our very low excluded segment number may be an underestimation because of the lack of automatic selection by the software and user dependent visual interpretation.

Conclusion

Velocity determination with two-dimensional speckle tracking seems to be a promising technique for echocardiography practice. However, it is in the early stages of development and the need for new software versions with more capabilities is clear. Indeed, we think that moderate size intraobserver agreement in our study is also points to this requirement. Moreover, we have one important question, which needs to be confirmed with further studies: Are the results obtained with the novel software comparable with the other software in the market?

Conflict of interest: None declared

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