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氏名	林（はやし） 秀隆（ひでたか）
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学位論文名	Evaluation of cardiac structure and function by real-time three-dimensional echocardiography （リアルタイム3Dエコー法による心臓の形態および機能評価）
論文審査委員	（主査） 教授 中谷 敏 （副査） 教授 村瀬 研也　教授 高島庄太夫

論文内容の要旨

Introduction

Cardiac function can be evaluated with echocardiography by minutely analyzing the left ventricular wall motion. Furthermore, echocardiography is useful to evaluate not only cardiac function but also heart valves, which dynamically change the position during a cardiac cycle.

Recent advancements of three-dimensional echocardiography have enabled us to evaluate cardiac function and dynamics of heart valves three-dimensionally. More accurate evaluation of cardiac function and dynamics of heart valves, and more accurate quantification of dimension and volume of cardiac structure can be achieved by three-dimensional echocardiography than two-dimensional echocardiography because cardiac performances are three-dimensional. In order to confirm the usefulness of three-dimensional echocardiography, we investigated three-dimensional dynamics of cardiac structures using three-dimensional echocardiography and compared with other modalities. (Study1 and Study2)

In addition, echocardiography can be repeatedly performed because it is noninvasive method, which is an advantage of echocardiography. We can follow-up changes in cardiac diseases over years with echocardiography. Therefore, we investigated mechanisms and changes of valvular heart disease using echocardiography. (Study3)

Study1

Background: Recently, it has become possible to evaluate left ventricular (LV) torsion by two-dimensional (2D) speckle tracking images. However, LV torsion is a three dimensional performance, which per se cannot be assessed by 2D speckle tracking method. The present study investigated the accuracy of the 2D speckle tracking method and real-time three-dimensional (3D) echocardiography in measuring LV rotation, comparing with the MRI tagging method.

Methods: I assessed LV apical rotation using the 2D speckle tracking method, real-time 3D echocardiography and MRI tagging method in 26 normal subjects, and compared the results of these three methods. LV apical rotation was measured just before the level in which the posterior papillary muscle was absorbed to the free wall.

Results: The degree of LV apical rotation evaluated by the 2D speckle tracking method (Δ02D) was significantly smaller than that evaluated by 3D echocardiography (Δθ3D) and the MRI tagging method (Δ0MRI) (Δθ2D vs Δθ3D; 7.3±2.8 vs 8.8±3.4°, $p<0.005$, Δθ2D vs Δ0MRI; 7.3±2.8 vs 9.0±3.4°, $p<0.005$). There were good correlations among Δθ2D, Δθ3D, and Δ0MRI, but agreement between Δθ3D and Δ0MRI (mean difference; 0.14±1.43°) was better than that between Δθ2D and Δ0MRI (mean diference; 1.68±1.89°).

Conclusion: The degree of LV apical rotation was underestimated with 2D speckle tracking method compared with the MRI tagging method, while it could be precisely measured by 3D echocardiography.

Study2

Background: Preoperative evaluation of aortic root diameters is important for determining surgical strategy in patients with aortic valve disease. The purpose of this study is to evaluate the usefulness of real-time three-dimensional echocardiography (3D-echo) for evaluation of aortic root diameters compared with two-dimensional echocardiography (2D-echo) and to evaluate aortic root dynamics.

Methods: We prospectively investigated 23 patients with aortic stenosis (AS) and 37 normal controls. With 2D-echo, aortic root diameters were measured from parasternal long-axis view. With 3D-echo, long-axis and short-axis views of the aortic root were reconstructed from the full-volume image, and aortic root diameters were measured at mid-systole, end-systole, mid-diastole and end-diastole. These aortic root diameters were compared between 2-D and 3-D measurements, regarding intraoperative and computed tomographic measurements as gold standard. In addition, dynamic changes of aortic root diameters during a cardiac cycle were evaluated.

Results: Aortic root diameters measured by 3D-echo were larger than those by 2D-echo (annular diameter: 19.6±2.1 vs 21.2±2.2mm, $p<0.0001$), and 3D measurements were closer to intraoperative and computed tomographic measurements than 2D measurements. Diameter of the aortic annulus increased during diastole, but the changes during a cardiac cycle were significantly smaller in patients with AS than in normal controls (2.0±2.2 vs 7.8±3.4%, $p<0.0001$).

Conclusions: Aortic root diameters can be more accurately measured by 3D-echo than 2D-echo. Dynamic change of the aortic annulus during a cardiac cycle was smaller in patients with AS. 3D-echo is useful for quantitative evaluation of the aortic root, including dynamics during a cardiac cycle.

Study3

Background: Severe tricuspid regurgitation (TR) sometimes develops late after left-sided valve surgery without left heart failure, pulmonary hypertension or rheumatic tricuspid valve. The purpose of this study is to investigate clinical

characteristics and mechanism of severe isolated TR late after left-sided valve surgery.

Methods: We retrospectively investigated 372 consecutive patients who underwent left-sided valve surgery between 1990 and 2003 and were followed up with echocardiography for at least 5 years. Mean follow-up period was 9.4 years. Clinical background, preoperative and postoperative echocardiographic parameters were evaluated.

Results: Among the 372 patients, severe isolated TR was detected in 23 patients, which developed at a mean of 8.6 years after surgery. Twenty-two of 23 patients had undergone mitral valve surgery. Multivariate logistic regression analysis identified the presence of preoperative atrial fibrillation and preoperative ejection fraction as independent determinants for the development of severe isolated TR. In patients with severe isolated TR, the tricuspid annular diameter and the right atrial area were already enlarged early after surgery and both of these increased prior to TR progression.

Conclusions: Severe isolated TR developing late after mitral valve surgery is not uncommon, thus it is important to recognize this disease entity. Annular dilatation was the main cause of isolated TR and serial echocardiographic data is important to detect progression of isolated TR and to assess its mechanisms.

論文審査の結果の要旨

心エコー検査は左室壁運動を分析することで心機能を評価でき、さらに心機能だけでなく心周期でダイナミックに位置を変化する心臓弁の評価に役立つ。3D心エコー法の進歩により心臓弁の3次元的な動作を評価することが可能となった。心機能と心臓弁の評価、心臓構造や容積評価は、心臓が三次元的動作をするために2D心エコー法より3D心エコー法がより正確に行える。この3D心エコー法の有用性を確認するため心臓の3次元動作を他のモダリティと比較し調査した。(Study1 と Study2)

さらに心エコー法の長所は非侵襲的な検査であり、繰り返し施行することができる事から、長年にわたって心臓病の経時的変化をフォローしてきた。このデータから心臓弁膜症の機序と変化を調査した。(Study3)

Study1

2Dスペックルトラッキング法により左室のねじれ運動を評価することが可能となってきたが、しかし左室のねじれ運動は三次元的な動きをするため正確な評価ができない。そこでリアルタイム3Dエコー法と2Dスペックルトラッキング法による評価をMRIタギング法と比較することで超音波装置による評価が可能であることを明らかにすることを目的とした。これら3つの方法を利用して正常26症例に対し収縮期回転角度を計測した結果、MRIタギング法と比べ3Dエコー法は収縮期回転角度を正しく評価したが、2Dスペックルトラッキング法は過小評価することを明らかにした。

Study2

大動脈弁疾患患者の手術計画に大動脈起始部径の評価は重要であり、リアルタイム3Dエコー法を用いて3次元的に大動脈起始部の動作を評価する事で有用性を確認するため、健常者37例と大動脈弁狭窄症患者23例を調査した。さらに比較するため2Dエコー法ならびにgold standardとしてMDCTを用いて計測した。この結果リアルタイム3Dエコー法の起始部径は2Dエコー法より大きく計測され、MDCTに近い値で計測できた事から、3Dエコー法により大動脈起始部径の正確な評価が可能である事が明らかとなった。さらに3Dエコー法を用いた検討により大動脈弁輪経は心周期で変化したが、大動脈弁狭窄症患者はその変化が小さい事を明らかにした。

Study3

重症三尖弁閉鎖不全は、左心不全や肺高血圧、リウマチ性三尖弁を伴わずに僧帽弁術後の遅発性変化としてときどき発症するが、この臨床的な特徴とメカニズムを調査した。1990年～2003年に左心系弁手術（僧帽弁および大動脈弁）を受け、5年以上心エコー検査でフォローした連続372例を調査した。372例中重症三尖弁閉鎖不全は23例に認められ、術後平均8.6年で進行した。その23例中22例は僧帽弁手術を受けた。重症三尖弁閉鎖不全患者は、術直後に三尖弁輪径と右心房面積が拡張し、両者とも三尖弁閉鎖不全の進行前に増大していた。進行とメカニズムを評価するため心エコー検査によるフォローが重要である事を明らかにした。

以上のことにより、本論文は博士（保健学）の学位授与に値するものと考えられる。