Three Dimensional Coronary Artery Motion Analysis with Biplane Coronary Angiography

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1. Introduction

For the past few years, coronary CT angiography is introduced and many investigators report the clinical usefulness of CT angiography. However, the temporal resolution of CT is 105 ms to 250 ms, so the subject, which do not move during that acquisition window can be imaged with acceptable quality. To obtain motion free image of heart, which is beating continuously, the optimal data acquisition window at the rest period of heart motion is needed. It is important to know when the coronary artery does not move and how the acquisition window change in various individual condition. The arising question regarding coronary artery motion is whether the all segment of coronary arteries show same movement pattern, in another word, whether there is one optimal acquisition window for all coronary artery segments. Another important question is that the effort to get lowering heart rate by beta-blocker is still needed with the high temporal resolution. This study will show the movement pattern of basal and mid to apical segment, and the change of movement pattern according to heart rate.

2. Materials and Methods

Twenty patients who underwent biplane coronary angiography were included in this study. The age of patients is 44 to 72 (mean 55). The 13 patients are male and 7 patients are female. The distribution of heart rate of patient at the time of angiography is 53-88 beat per minute (mean 69). The anteroposterial projection image and true lateral images were acquired simultaneously with biplane coronary angiography (Phillips, Netherlands) for more than 5 seconds at the frame rate of 30 f/s. The cine angiographies were image was obtained with breath-hold to eliminate the respiratory movement. The acquired cine images are separated to serial bitmap still images by ACOM PC (Siemens, Germany) software from R-peak to next R-peak of the concurrently recorded EKG signal. Total four sets of 20-35 still images of one R-R interval are analyzed. Total eight landmarks from branching points were selected, four at basal segment and four at mid to apical segment were pointed as 2D coordinates scene by scene by UTHSCSA ImageTool (Texas, USA) software. The landmarks are os of LAD, os of obtuse marginal branch, os of acute marginal branch, os of posterior descending artery and four mid to apical branching point of LAD, OM, AM, PDA. The two sets of coordinates are obtained for each landmark. The zoom factors and absolute locations of both coordinates are different due to both projection have different zoom factor and position. The scale alignments and zoom factor are corrected by comparing distribution of the value of Z-axis coordinates, which is expected as identical on both view points by Levenberg-Marquardt routine. Finally three-dimensional coordinates are obtained. The three dimensional velocities of each points are calculated by vector analysis. The total path distance for 100ms and 200ms was obtained point by point. The path distance presented by pixel was converted to absolute mm scale by using the diameter of catheter for angiography. If the CT scanning with 100 ms temporal resolution, the total path distance present the absolute amount of movement of coronary artery during data acquisition. The path distance for 100ms and 200ms were plotted along the start point of data acquisition window in the cardiac cycle. The path distance less then 1.5 mm for 100ms or 200ms was accepted as motion free acquisition window in which the image of coronary artery can be obtained without motion artifact. The length of motion free acquisition window analyzed and compared according to segment and heart rate.

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3. Result

The coronary artery shows different pathway during systolic phase and diastolic phase. The mid to apical segment coronary artery shows longer resting period than basal segment coronary artery. The starting point of 100ms acquisition window for less than 1.5mm total movement of basal segment at the 31-38% and 59-74% of cardiac cycle. The tolerable range of motion free acquisition window of diastolic phase decreased with the increase of heart rate. The heart rate 70-77 bpm the tolerable ranges of motion free acquisition window of diastolic phase are not different from that of systolic phase. There is no motion free acquisition window of diastolic phase in the patient with heart rate above 80. Only the patients with heart rate higher than 65 bpm shows sufficient motion free acquisition window of 100ms and 200ms. With heart rate increased the systolic acquisition window does not changed but the diastolic acquisition window is shortened and disappeared.

4. Discussion

According to our result, the basal segment of coronary artery and mid to apical segment coronary artery show different movement pattern. The mid to distal segment shows lower motion range and longer resting period,however the maximum rest period is slightly different from that of basal segment. The difference is not so large, with the present temporal resolution this difference may do not make a problem, but there is a possibility of multiphase reconstruction is necessary to view all coronary arteries. It is well known that the image quality of CT coronary angiography is dependent to heart rate. The CT coronary angiography image quality is markedly degraded in the cases of high heart rates. There are two way to solve this problem. One is the lowering heart rate by use of beta-blocker, another is improving the temporal resolution of CT. Use of beta-blocker is the best way to obtain high quality CT coronary angiography to present. The recent fastest CT machine has 420ms gantry rotation time. To reconstructing one axial image, at least 180 degree gantry rotation is needed. So the temporal resolution of CT is 210ms. With the segmented reconstruction algorithm, in which the one axial image is reconstructed from two to four heart beat, the temporal resolution of CT is up to 105 - 60ms. However there are some problem in using the segmented reconstruction algorithm. To gain the optimal result from segmented reconstruction algorithm the heart rate is optimal to the gantry rotation time. If the synchronization of heart rate and gantry rotation occurs, the segmented reconstruction algorithm does not work at all. The another problem is beat by beat variation of heart beat. This beat by beat variation make worse effect in segmented reconstruction algorithm. In segmented reconstruction algorithm, one axial image is reconstructed by two or four heart beat data acquisition. That means uniformity of heart beat is essential to get good quality image in segmented reconstruction technique. However, the sinus arrhythmia is normally seen in the most of patients. So the minor degree of beat by beat variation is inevitable during cardiac CT scanning. In addition breath-holding during CT scanning aggravate the beat by beat variation. One possibility in improvement of temporal resolution is the faster gantry rotation time. The next version of CT may shows 375ms gantry rotation time and the temporal resolution of this machine will be 188ms without segmental reconstruction. Due to the very high G-force of gantry rotation, the shortening of gantry rotation time has limitation vividly. Even though the mechanical improvement make it possible to image the heart with CT, the temporal resolution will have definite limitation for a while. In this study we investigate the optimal acquisition window for coronary artery with 100 ms and 200 ms temporal resolution. The most impacted fact in this study is that the patient with heart rate of 70-77 bpm shows very limited acquisition window at diastolic phase that cannot be covered with 200ms acquisition window and the patient with heart rate of exceed 80 bpm shows no acquisition window at diastolic phase. That means the beta-blocker is still need with the high temporal resolution CT scanner. We made one assumption that the total path distance exceed 1.5 mm during the acquisition window is the limitation of motion artifact of CT coronary angiograpy. The further study of coronary motion artifact according the amount and pattern of movement during data acquisition may be helpful.

5. Conclusion

The mid to apical segment coronary artery shows longer resting period than basal segment coronary artery but the extent is not so large to affect acquisition window. The heart rate below 70 bpm is important factor to get motion free CT coronary angiography.