Image quality of 16-slice computed tomography coronary angiography in patients with complete left bundle branch block

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Key words: *multislice computed tomography coronary angiography; left bundle branch block; image quality.*

Summary. *Objective. Noninvasive diagnosis of coronary artery disease in patients with left bundle branch block is challenging. Multislice computed tomography can be useful in this population; however, quality of images depends on the patterns of myocardial contractions. We investigated the influence of left bundle branch block on image quality of multislice computed tomography coronary angiography.*

Materials and methods. Multislice computed tomography coronary angiography was performed in 30 patients with left bundle branch block and 30 patients without conduction disturbances. Image quality of each coronary segment was visually assessed and rated on a five-point scale (1=highest quality).

Results. Average image quality score in the best cardiac cycle phase did not differ significantly between groups (1.71±0.59 in the left bundle branch block group vs. 1.60±0.57 in the control group, P=0.46). In the left bundle branch block group, a significantly lower image quality score was observed in end-systolic cardiac phase (2.67±0.6 vs. 2.22±0.65 in the control group, P=0.007), whereas no difference was demonstrated in mid-diastolic phase (1.73±0.6 vs. 1.69±0.66 in the control group, P=0.81). After image assessment in multiple cardiac phases, an increase in image quality score was higher in the left bundle branch block than in the control group (0.2±0.17 vs. 0.11±0.14, P=0.003). A negative correlation was observed between image quality score and both the heart rate and heart rate variability in both groups (P<0.001).

Conclusion. A nonsignificantly lower overall image quality of multislice computed tomography coronary angiography was demonstrated in the left bundle branch block group. In the presence of left bundle branch block, image quality in the end-systolic phase was significantly lower. Image assessment in multiple phases increased overall image quality and is therefore advisable in patients with left bundle branch block. Increased heart rate and heart rate variability worsened image quality in both groups.

Introduction

Left bundle branch block (LBBB) is an electrical conduction disturbance that can be present both in healthy patients and patients with various cardiovascular diseases (1). Data from epidemiological studies suggest that bundle branch block, especially LBBB, is an independent risk factor for cardiovascular morbidity and mortality in patients with heart diseases (2). Detection of coronary artery disease (CAD) in this patient population in particular has obvious implications for management.

Nevertheless, noninvasive detecting of myocardial ischemia in patients with LBBB remains challenging due to low accuracy of commonly used noninvasive diagnostic tools, such as stress electrocardiographic (ECG) study, myocardial perfusion imaging, and stress echocardiography. Exercise ECG is not reliable in this patient population due to low specificity (3). Concerning myocardial perfusion scintigraphy, anteroseptal perfusion defects may be demonstrated in the absence of CAD (4). Atypical anteroseptal wall motion also challenges the interpretation of inducible wall motion abnormalities on stress echocardiography (5).

Invasive assessment of coronary arteries by means of conventional coronary angiography in the presence of LBBB is a gold standard, although it is related to high costs and low but definite risk of serious and life-threatening complications. Moreover, CAD is not present in an average of 60% of patients with LBBB, who undergo invasive coronary angiography (6). Recently, multislice computed tomography (MSCT) has been introduced as a tool for noninvasive visua-

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lization of the coronary arteries. State-of-the-art 16- and 64-slice MSCT scanners permit detection of obstructive coronary lesions with good sensitivity and specificity (7). However, LBBB may influence image quality as it is related to atypical heart contraction and relaxation. The aim of this study was therefore to evaluate the image quality of MSCT coronary angiography in patients with LBBB.

Materials and methods

Study population

Between February 2006 and April 2007, a total of 60 patients with suspected or known CAD were included in the study. Thirty patients (14 males; mean age, 65.3±9.4 years) were diagnosed to have a complete LBBB according to the following ECG criteria: QRS duration of ≥0.12 s, QS or rS pattern with a small r wave and a positive T wave in V_1 lead, a single R wave with its peak after the initial 0.06 s in I and V_6 leads, T waves with their polarity usually opposite to the slurred component of the QRS complex. The remaining 30 patients (20 males; mean age, 61.7±8.9 years) with no conduction disturbances on the surface ECG were matched to the LBBB group according to the heart rate and served as a control group.

Exclusion criteria were atrial fibrillation or frequent extrasystoles, advanced heart failure (left ventricular ejection fraction of <40%), previous myocardial infarction with ST-segment elevation, renal insufficiency (serum creatinine level of >120 μmol/L), inability to sustain breath-hold for 20 s, known allergy to iodinated contrast medium.

The study protocol was approved by the local Institutional Ethics Committee, and written informed consent was obtained before including each patient into the study.

MSCT image acquisition

Patients were scanned with a 16-slice MSCT scanner (GE LightSpeed Pro[16], Milwaukee, Wis, USA). First, scan for calcium score quantification was performed with the following parameters: collimation, 16×1.25 mm; tube voltage, 120 kV; tube current, 300 mA; gantry rotation time, 500 ms; prospective ECG triggering. Subsequently, MSCT coronary angiography was performed. A bolus-tracking "Smart-prep" technique was used to monitor the arrival of contrast in the ascending aorta and the initiation of the scan. The contrast material (Ultravist 370, 370 mg iodine/mL; Schering AG, Berlin, Germany) was injected at a rate of 4.5 mL/s through an 18-G needle placed in the antecubital vein. The volume of nonionic contrast media used ranged from 90 to 120 mL depending on the patient's weight, scan time, and heart rate. The following scan protocol was used: collimation of 16×0.625 mm at a variable pitch (ranging between 0.22:1 and 0.3:1 depending on the patient's heart rate), craniocaudal scan direction, tube voltage of 120 kV, tube current of 500–600 mA (depending on the patient's body weight), gantry rotation time 400 ms, retrospective ECG gating. The "Burst" multi-sector acquisition protocol was applied, which uses two sectors of consecutive cardiac cycles to reconstruct each axial image and provides 100-ms temporal resolution. Twenty-five patients (83.3%) in the LBBB group and 23 patients (76.6%) in the control group were receiving beta-blockers as part of their baseline treatment (Table). No additional beta-blockers were given before MSCT scan.

MSCT image reconstruction and analysis

The images were reconstructed in 10 phases of the R-R interval (0% to 90% at the increment of 10%) and sent to the workstation with dedicated software

***Table.* Patient characteristics**

Characteristic	LBBB group (n=30)	Control group (n=30)	*P* value
Age (yrs)	65.3±9.4	61.7±8.9	0.1
Women, n (%)	16 (53.3%)	10 (33.3%)	0.12
Body mass index (kg/m²)	27.5±5.4	29.7±3	0.18
Beta-blockers, n (%)	25 (83.3%)	23 (76.7%)	0.52
Cardiovascular risk factors			
Hypercholesterolemia, n (%)	17 (56.7%)	19 (63.3%)	0.6
Hypertension, n (%)	24 (80%)	19 (63.3%)	0.15
Smoking, n (%)	7 (23.3%)	11 (36.7%)	0.26
Family history of CAD, n (%)	20 (66.7%)	18 (60%)	0.6
Diabetes mellitus, n (%)	3 (10.0%)	2 (6.7%)	0.64

CAD – coronary artery disease; LBBB – left bundle branch block.

for offline analysis (Advantage Workstation 4.2, GE Milwaukee, Wis, USA). Coronary arteries were divided into 15 segments according to the American Heart Association guidelines (8). MSCT images were assessed on thin-slab maximum intensity projections in multiple projections, followed by evaluation of curved multiplanar reformations and axial images. All coronary segments were analyzed by two experienced observers (A.J. with a 2-year experience and J.Z. with a 1-year experience in coronary CT angiography). Image quality was visually assessed by the presence of motion artefacts and subsequently classified into five groups: (1) excellent image quality (sharply delineated vessel borders); (2) minor stepwise artefacts and mild blurring of the segment; (3) moderate artefacts and moderately blurred vessel borders; (4) severe motion artefacts and severely blurred vessel borders; and (5) vessel structures not evaluable (Fig. 1). Images scored between 1 and 3 were considered of sufficient diagnostic quality. Analysis of image quality was performed on a per-segment basis in every cardiac cycle phase and compared between the two patient populations. For any disagreements in data analysis, consensus agreement between the two observers was used.

Statistical analysis

Continuous variables are expressed as means and standard deviations. Categorical variables are presented as absolute frequencies and percentages. Differences between the parameters of the two patient groups were tested by unpaired *t* test for continuous variables and by paired *t* test in the same patient group at the 95% confidence level (two-tailed). To compare categorical variables, chi-square test was used. To quantify the interobserver agreement, Cohen's κ value was calculated. Pearson's correlation analysis was performed to compare the average image quality score in the best heart cycle phase with the average heart rate and heart rate variability. The *P* value of <0.05 was regarded as statistically significant. Statistical analyses were performed with SPSS software, release 13.0 (SPSS Inc., Chicago, Ill, USA).

Results

The baseline patient characteristics are presented in Table. No significant differences in age, body mass index, and CAD risk factors were observed between the two patient groups.

MSCT scan was performed without complications in all patients. The mean heart rate during data acquisition was comparable in both groups (65.3±7.59 beats per minute in the LBBB group and 65.2±8.3 beats per minute in controls; *P*=0.9). The heart rate varia-

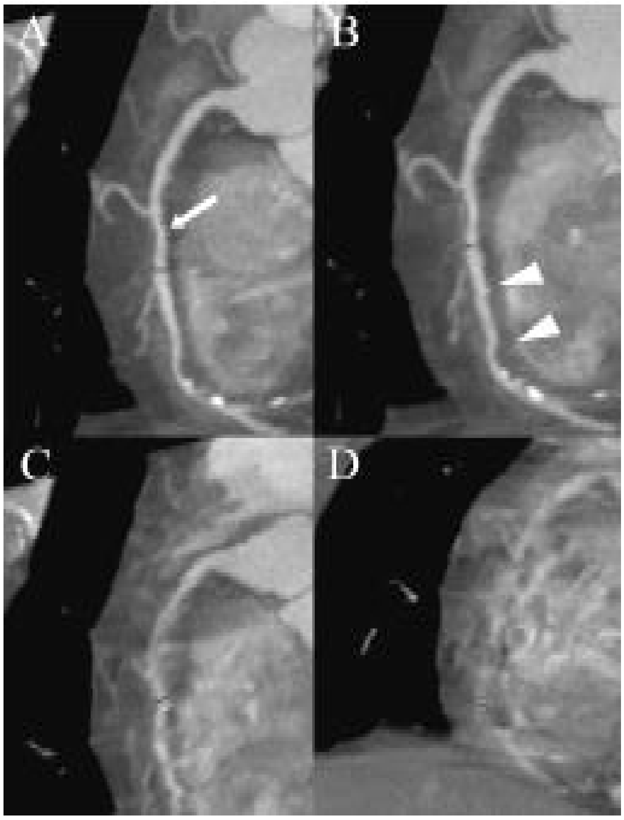

Fig. 1. **Image quality scoring on maximum intensity projection images of multislice computed tomography coronary angiography using a five-point scale**
A – well-defined contours (image quality score of 1) are observed in the proximal segment of the vessel, while the middle and distal portions of the same artery show minor stepwise artefacts (image quality score of 2) (arrow); B – moderate stepwise artefacts (image quality score of 3) (arrowheads); C – severe motion artefacts (image quality score of 4); D – the vessel structure is not evaluable (image quality score of 5).

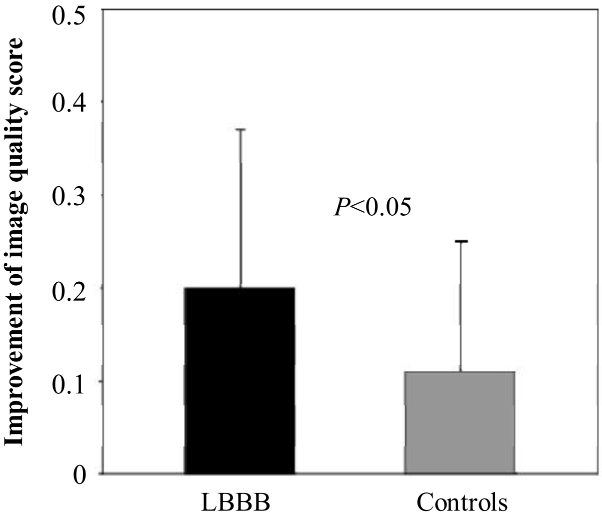

Fig. 2. **Improvement of image quality score after image assessment in multiple cardiac phases as compared to assessment only in the best cardiac cycle phase (*P*=0.03)**
LBBB – left bundle branch block.

bility during data acquisition in the groups was also similar (2.99±1.6 beats per minute in the LBBB group and 2.69±1.94 beats per minute in the control group; *P*=0.52). Left ventricular ejection fraction was slightly but not significantly lower in the LBBB group as compared to the control group (46.64±5.14% vs. 49.69±5.91%; *P*=0.09).

MSCT image analysis

In total, 857 segments with a diameter of ≥1.5 mm were evaluated (426 in patients with LBBB and 431 in the control group). Interobserver agreement on image quality was good (κ=0.78). When one cardiac phase with the best image quality (with the highest average score of all segments) was selected, 366 segments (86%) in LBBB and 386 segments (90%) in the control group were of diagnostic image quality (*P*=0.1).

First, average image quality scores in the cardiac cycle phases with the highest overall image quality were compared between the two groups. The average image quality score in the best phase was slightly but not significantly lower in the LBBB group as compared to the control group (1.71±0.59 vs. 1.60±0.57; *P*=0.46). Secondly, coronary segments with better image quality score observed in the other cardiac cycle phases were identified. The corresponding segments in the cardiac phase with the best image quality were replaced by these segments. When the replacement was performed, improvement of the image quality score was significantly higher in the LBBB group (0.2±0.17) as compared to the control group (0.11±0.14; *P*=0.03) (Fig. 2). An example of improved image quality in a patient with LBBB, when reconstructions in multiple cardiac phases are assessed, is provided in Fig. 3.

Comparison of image quality scores in the two patient groups when reconstruction was made in end-systolic (40–50%) and mid-diastolic (70–80%) cardiac cycle phases revealed a statistically significant difference in image quality score in end-systolic phase (2.67±0.6 in the LBBB group and 2.22±0.65 in the control group; *P*=0.007). No difference in image quality score was observed in mid-diastolic phase (1.73±0.6 in LBBB group and 1.69±0.66 in control group; *P*=0.81) (Fig. 4). The mean image quality score in the LBBB group was significantly lower in end-systolic cardiac cycle phase for all three major coronary arteries as compared to the control group (3.03±0.69 vs. 2.52±0.5 for right coronary artery, *P*=0.007; 2.49±0.64 vs. 2.12±0.45 for left main and left anterior descending arteries, *P*=0.01; 2.67±0.59 vs. 2.06±0.52 for left circumflex artery, *P*<0.001). End-systolic phase was selected as the best cardiac cycle phase in

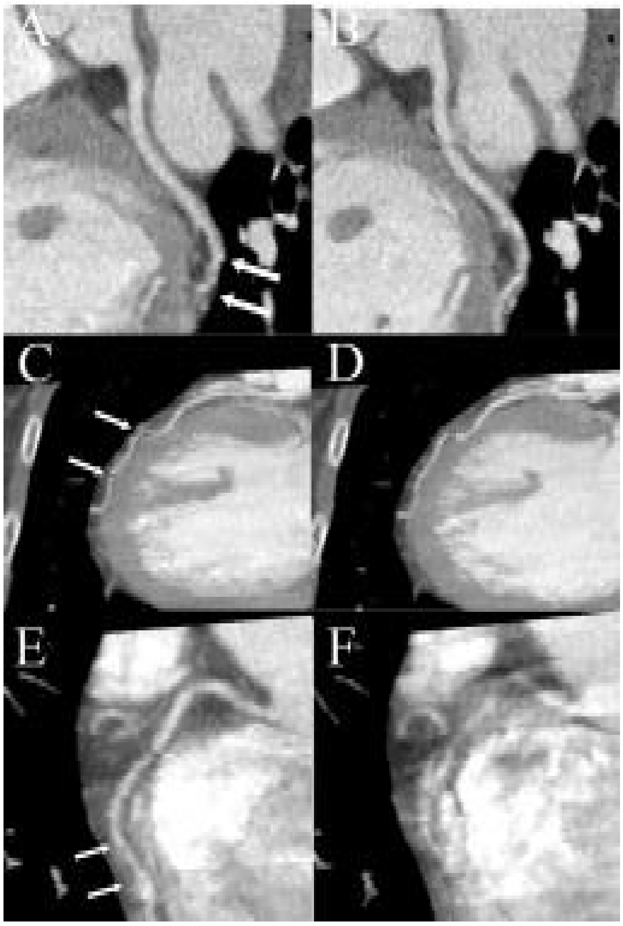

***Fig. 3.* Images of a 67-year-old female with complete left bundle branch block illustrate incremental value of multiphase assessment of multislice computed tomography coronary angiography (heart rate during data acquisition was 66.8±2.95 bpm)**

A and B – maximum intensity projection images demonstrate stepwise motion artefacts of the middle portion of the left circumflex artery (arrows) in the 70% cardiac cycle phase (A), which are less prominent in the 80% cardiac cycle phase (B). C and D – minor motion artefacts are observed on maximum intensity projection images of the left anterior descending artery (arrows) in the 70% cardiac cycle phase (C), compared with the 80% cardiac cycle phase (D), where sharply delineated contours without discontinuation are presented. E and F – motion artefacts are seen on maximum intensity projection images of the proximal and middle portions of the right coronary artery (arrows), although the image quality is still diagnostic in the 70% cardiac cycle phase (E) whereas nondiagnostic quality is observed in the 80% cardiac cycle phase (F).

5 of 30 (16.7%) patients in the LBBB group and in 8 of 30 (26.7%) patients in the control group (*P*=0.3).

A negative linear correlation was observed between mean image quality score in the best cardiac phase and the average heart rate in both groups: *r*=0.73 (*P*<0.001) in the LBBB group and *r*=0.67 (*P*<0.001) in the control group. Similar correlation was

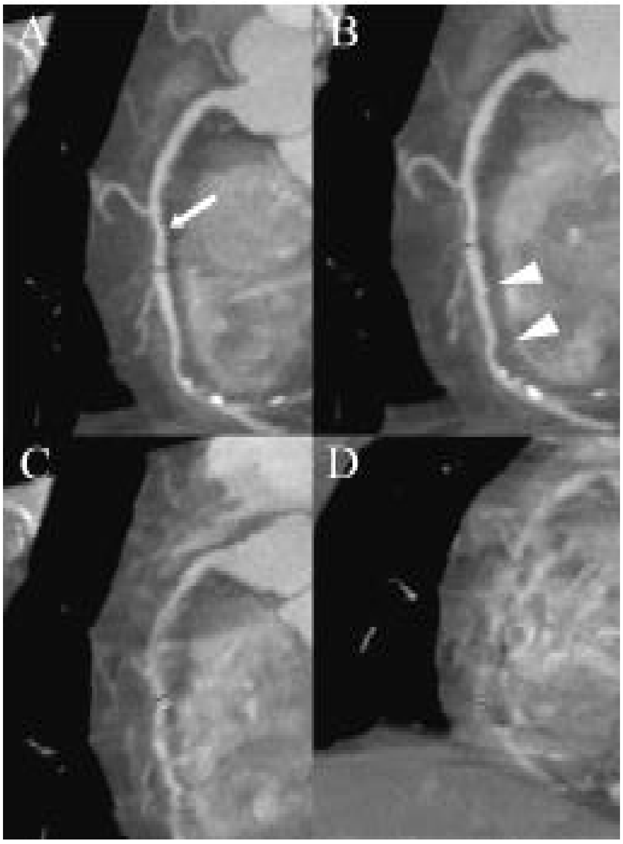

Fig. 4. **Comparison of mean image quality score in the end-systolic (40–50%) and mid-diastolic (70–80%) cardiac cycle phases in left bundle branch block and control groups**

Image quality was significantly lower in end-systolic phase in the left bundle branch block group ($P<0.01$) and comparable in mid-diastolic phase in both groups ($P=0.81$).

observed for the heart rate variability: $r=0.58$, ($P<0.001$) in the LBBB group and $r=0.51$, ($P<0.001$) in the control group.

Discussion

We have tested hypothesis that LBBB (which causes dynamic interventricular dyssynchrony throughout the cardiac cycle) may influence the image quality of MSCT coronary angiography.

The presence of LBBB makes noninvasive identification of CAD with accepted diagnostic methods more challenging. Therefore, MSCT coronary angiography as a novel noninvasive diagnostic tool could be more suitable in this patient population (9). One of the main challenges for MSCT coronary angiography remains residual cardiac motion artefacts because of continuous and complex coronary artery tree motion during cardiac cycle. Due to different anatomic location, each coronary artery has a distinct motion pattern during the heart cycle. Indeed, motion of the proximal parts of the right coronary artery and the left circumflex artery depends on both the atrial and ventricular contractions, while motion of the left anterior descending artery, distal parts of the left circumflex and the right coronary artery mainly depends on ventricular contraction (10).

The influence of the heart rate and heart rate variability on MSCT image quality was demonstrated in numerous studies (11, 12). However, data on the image quality of MSCT coronary angiography in patients with LBBB are sparse.

Effect of LBBB on the image quality

In patients with LBBB, left ventricular diastolic filling period and ejection time are shortened, whereas isovolumetric contraction and relaxation times are prolonged as compared to subjects without LBBB (13, 14). Indeed, Grines et al. have found an interventricular delay of 85±31 ms measured by radionuclide ventriculography (14). On the contrary, in patients without bundle branch block, contraction of the ventricles is almost synchronous (15). Our results demonstrate that image quality score in the best cardiac cycle phase is slightly but not significantly lower in the LBBB group than in the controls. When images were evaluated in multiple cardiac phases, image quality improved in both groups, but incremental value of multiphase assessment was higher in the LBBB group. This finding suggests that asynchronous contraction slightly worsens image quality, and reconstruction in multiple phases is helpful in ensuring the diagnostic accuracy at the best possible level in patients with LBBB.

Another finding of this study is a significantly lower mean image quality score in the end-systolic cardiac cycle phase in the LBBB group patients as compared to the controls. It can be explained by prolonged ventricular contraction during systole in patients with LBBB, which results in a higher probability of motion artefacts during the end-systolic phase. Nevertheless, in some patients (5 of 30 patients in our study) with LBBB, the end-systolic heart cycle phase was selected as the best phase. Therefore, the end-systolic phase should not be excluded from analysis. No particular artery of three main coronary branches was found to be responsible for this worsening in the image quality. This can be explained by the complex three-dimensional heart motion during the cardiac cycle, which involves all three coronary arteries (16).

Effect of the mean heart rate and heart rate variability on the image quality

Heart rate and heart rate variability are well-established factors influencing the image quality on MSCT coronary angiography (11, 12). When heart rates are higher, diastolic heart cycle period shortens more than systolic, which can result in shifting of the best image quality phase from the mid-diastolic to end-systolic. Variable heart rate is also related mainly to the changes in the diastolic time interval, while duration of systole is more constant. In studies with 16-slice MSCT, a negative correlation between average heart rate during scanning and image quality was found (12, 17). A newer 64-detector row CT generation with faster gantry rotation times is less sensitive to elevated heart rates, although heart rate variability still significantly worsens image quality (18). Our study also reported a significant negative correlation between heart rate, heart rate variability and image quality in the best cardiac cycle phase in both groups, suggesting that these factors have similar effect in patients with LBBB and the subjects without the electrical conduction disturbances. Our findings are in accordance with findings by Ghostine el al., who investigated image quality of MSCT coronary angiography in 66 patients with LBBB (9). Similarly to our study, the authors observed a decreasing image quality as the heart rate increased. Thus, heart rate lowering with beta-blockers for improving image quality should be advisable in patients with LBBB, as it was already reported in studies on patients without LBBB (19, 20).

Limitations

Several limitations of the study should be acknowledged. Visual image quality scoring is rather subjective and may be biased, although good interobserver agreement indicates that such bias should not be significant. An increment in the position of image reconstruction window of 10% may be too long to detect more subtle coronary motion differences.

Conclusions

Our study has demonstrated insignificantly decreased overall image quality of multislice computed tomography coronary angiography in patients with left bundle branch block as compared to patients without conduction disturbances. Nevertheless, the image quality was significantly lower in the end-systolic phase in the presence of left bundle branch block. Image assessment in multiple phases increased overall image quality and is therefore advisable in patients with left bundle branch block. Increased heart rate and heart rate variability significantly worsen the image quality both in patients with and without left bundle branch block.

Pacientų, kuriems nustatyta kairiosios Hiso pluošto kojytės blokada, vainikinių arterijų daugiasluoksnės kompiuterinės tomografijos angiografijos vaizdų kokybė

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Raktažodžiai: vainikinių arterijų daugiasluoksnė kompiuterinė tomografija, kairiosios Hiso pluošto kojytės blokada, vaizdų kokybė.

Santrauka. *Darbo tikslas*. Neinvazinė išeminės širdies ligos diagnostika, esant kairiosios Hiso pluošto kojytės blokadai, yra sudėtinga. Daugiasluoksnės kompiuterinės tomografijos tyrimas gali būti informatyvus tyrimo metodas, esant šiam laidumo sutrikimui, tačiau vaizdų kokybė priklauso nuo širdies susitraukimų dažnio ir pobūdžio, o, esant kairiosios Hiso pluošto kojytės blokadai, skilveliai susitraukia asinchroniškai. Šio darbo tikslas – įvertinti kairiosios Hiso pluošto kojytės blokados įtaką daugiasluoksnės kompiuterinės tomografijos angiografijos vaizdų kokybei.

Tyrimo medžiaga ir metodai. Vainikinių arterijų daugiasluoksnės kompiuterinės tomografijos angiografija atlikta 30 pacientų, kuriems nustatyta kairiosios Hiso pluošto kojytės blokada, ir 30 pacientų be laidumo sutrikimų. Segmentų kokybė vizualiai vertinta 5 balų skalėje (1 balas – aukščiausia kokybė).

Rezultatai. Vaizdų kokybės vertinimo vidurkis geriausioje širdies ciklo fazėje tarp grupių statistiškai reikšmingai nesiskyrė (1,71±0,59 kairiosios Hiso pluošto kojytės blokados grupėje, 1,60±0,57 kontrolinėje grupėje, p=0,46). Kairiosios Hiso pluošto kojytės blokados grupėje nustatyta daug blogesnė vaizdų kokybė galinėje sistolinėje širdies ciklo fazėje (2,67±0,6 kairiosios Hiso pluošto kojytės blokados grupėje, 2,22±0,65 kontrolinėje grupėje, p=0,007), o vidurinėje diastolinėje fazėje statistiškai reikšmingo skirtumo nebuvo (1,73±0,6 kairiosios Hiso pluošto kojytės blokados, 1,69±0,66 kontrolinėje grupėje, p=0,81). Iš visų širdies ciklo fazių atrinktus kokybiškiausius segmentus, palyginus su vienos širdies ciklo fazės segmentais, kurioje kokybės vidurkis buvo aukščiausias, kairiosios Hiso pluošto kojytės blokados grupėje kokybės skirtumas buvo statistiškai reikšmingai didesnis (0,2±0,17 kairiosios Hiso pluošto kojytės blokados, 0,11±0,14 kontrolinėje grupėje, p=0,003). Abiejose grupėse nustatyta neigiama koreliacija tarp vaizdų kokybės, širdies susitraukimų dažnio ir jo variabilumo (p<0,001).

Išvados. Kairiosios Hiso pluošto kojytės blokados grupėje vainikinių arterijų vaizdų kokybė geriausioje širdies ciklo fazėje nuo kontrolinės grupės statistiškai reikšmingai nesiskyrė, tačiau buvo blogesnė galinėje sistolinėje širdies ciklo fazėje. Segmentų įvertinimas visose širdies ciklo fazėse kairiosios Hiso pluošto kojytės blokados grupėje statistiškai reikšmingai pagerino vaizdų kokybės vidurkį, todėl šis vertinimo būdas rekomenduotinas esant kairiosios Hiso pluošto kojytės blokadai. Padidėjęs širdies susitraukimų dažnis ir jo variabilumas blogina vaizdų kokybę abiejose grupėse.

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