Initial Study of Left Ventricular Function after Emergency Myocardial Contusion by Dual Source Computed Tomography in a Pig Model

Shan-xing Ou[1], Li Zhang[1], Shu-fei Ou[1], Guang-ming Peng[1], Yuan-xing Guo[1], Bin Li[2], Xiao-rong Li[1], Song-na Li[1], Fang Long[1], Ye-kuo Li[1], Yu-ke Chen[1], Min Qian[1], Hai-ling Liu[1]

[1]Department of Radiology, General Hospital of Guangzhou Military Command of PLA, Guangzhou, China
[2]School of Automation Science and Engineering, South China University of Technology, Guangzhou, China

Abstract

The aim of our study was to investigate the irregularity changes of the left ventricular functional after emergency myocardial contusion in experimental pigs.

16 BAMA experimental pigs were selected and striked to establish myocardial contusion model. Vital signs of these pigs were conventionally monitored, and DSCT scanning were performed at time points before striking, post striking immediately, 2h, 4h and 8h after striking. The index included ejection fraction (EF), the wall thickness of left ventricle at the end of systole and diastole phase, and fraction shorting (FS). The data was analyzed by one way ANOVA.

After severe myocardial contusion, the heart rate of pigs kept lower, the breathing frequency lower lightly. While the mean arterial pressure (MAP) decreased immediately and increased gradually at 4h and 8h after myocardial contusion, the function of left ventricle changed obviously. The EF descended markedly, the descended rate was 18.8%, 21.3%, 16.74%, and5.3%, respectively. There is statistic difference between the 2h and that of before striking ($P < 0.05$). The wall thickness of the left ventricle is different from others at 2h.

DSCT is a very useful potential tool to evaluate the experimental myocardial contusion. Specially, the functional change of the left ventricule and the degree of injury of pigs could be assessed by DSCT after emergency myocardial contusion.

1. Introduction

The heart injury rate was about 16% in the closed thoracic injury. The pericardium rupture, myocardial contusions, structural damage or even cardiac broken may happen because of the compressed violence or deceleration injury when the closed thoracic injury. Blunt cardiac injury early may be fatal due to early cardiac rupture, cardiac tamponade, and severe hemorrhagic shock. Therefore, early diagnosis will not only guide first-aid, but also provide the basis for taking appropriate treatment and follow-up, which could affect the prognosis of patients directly. In our study, we observed the change of left ventricular function of the acute myocardial contusions of experimental pigs at early time, and assessed the diagnostic value of the DSCT.

2. Methods

2.1. Subjects

16 BAMA experimental pigs were selected, aged 150-180d, weight 15-26 kg (average 18.64KG), length 60-72cm(average 64.57cm). The emergency myocardial contusion models were established by the BIM-□striker. The striking parameter: driving force 7.01KN, the radius of sectional 1.9cm. Vital signs of pigs including the heart rate, the breathing frequency and the average artery pressure were conventionally monitored at time points as before striking, post striking immediately, 2h, 4h and 8h after striking. The dual-source CT scanning was performed and the imaging was analyzed. The animals were killed using 10% KCI. The heart was cut into slices with the thickness 5mm on the short axial. The slices were stained with TTC (37°C, 20min). The normal myocardium turned to be red, the ischemia myocardium brick-red, but the necrosis myocardium kept primitive colour.

2.2. Data and statistical analysis

The monitoring index included EF, the wall thickness of left ventricle at the end of systole and diastole phase, and fraction shorting (FS). The data was analyzed by one way ANOVA with SPSS 16.0 and a *P* value of less than

0.05 was considered statistically significant.

3. Results

3.1. Results analysis

It is instantly showed decreased heart rate, fall of blood pressure, erased respiratory frequency and decreased average arterial pressure, which was at minimal level in the period of post-trauma. It demonstrated obvious swelling, decrease of the tissue density in the local part of the ventricular wall, and a few pericardium fluids. Left ventricular diastolic and systolic function at 2h post-trauma was lower than that of pre-trauma. At 8h post-trauma left ventricular diastolic and systolic function was restored obviously.

Ejection fraction: the left ventricular function changed more obviously at early period after trauma, while the ejection fraction decreased significantly. The descent value was 10.47%, 17.68%, 13.14%, 0.82% and after trauma at 2h, 4h and 8h, respectively.

Fraction shorting: fraction shorting was different at each period, but the differences had no significant meaning. The fraction shorting of pre- and post- trauma was 17.14%, 12.02%, 15.17%, 13.03%, and 16.42%, respectively.

The change of ventricular wall thickness: the ventricular wall average thickness of pre-trauma was 0.47cm, and that was 0.34cm, 0.21cm, 0.32cm, 0.41cm at 2h, 4h, and 8h after trauma, respectively. As given in Table 1.

Groups		EF (%)	FS (%)	WT (mm)
Before		55.85±7.56	17.14±8.28	0.47±0.21
After	0h	47.10±13.16	12.02±7.56	0.34±0.23
	2h	39.89±17.00	15.17±8.69	0.21±0.24
	4h	44.43±15.72	13.03±11.61	0.32±0.23
	8h	56.75±5.39	14.85±8.47	0.41±0.16

Table 1. Variation of left ventricular function of pre- and post- myocardial contusion.
*: EF=Ejection Fraction, FS= Fraction Shortening, WT=Wall Thickness.

3.2. Specimen observation

The little punctuated hemorrhage could be seen under epicardium, and slabby hemorrhage observed under endocardium at naked eyes. The common hemorrhage position were the apex of heart, left septal and around papillary muscles, left atrium, right septal surface and right atrium. The extensive injured and necrosis regions of myocardial ischemia were obtained at the apex of heart, left septal surface, frontal wall and lateral wall of left septal on TTC staining, which was distributing into endocardium and epicardium. Necrosis areas were illustrated in all layers, specially in apex of heart, septal, and the myocardial ischemia of the papillary muscles. As is shown in Figure1.

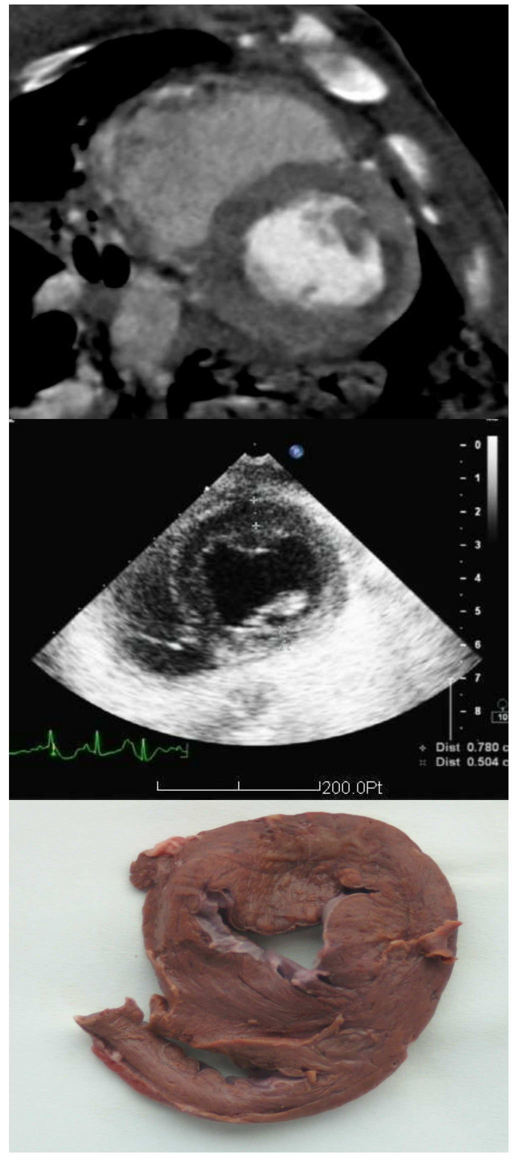

Figure 1. Illustration of the cardiac injury location. A is imaging of DSCT, B is imaging of ECHO, and C is the picture of pathology.

4. Discussion and conclusion

Blunt cardiac injury caused by myocardial contusion (MC) is the most common, occurring in approximately 16%, seen in traffic accidents, or injuries from falls, and severe crush injury [1, 2]. There are various common complications of the severe myocardial contusion, such as severe arrhythmias, congestive heart failure and cardiogenic shock. Other serious complications after myocardial contusion include cardiac rhythm disorders, hypotension and oliguria, of which the rate is 23% and the mortality rate 4% [3]. The purpose of imaging assessment is a key to make diagnosis and contribute to the early therapy in myocardial contusion, which holds significant clinical value.

Since 1764, the first cardiac injury case due to blunt force or traumatic chest was reported. Until 1932, ECG was first done on experimental injury of heart caused by blunt injury in chest. In the 1970s, much work by foreign scholars has been devoted to study the blunt cardiac injury. So far, the research of ECG and ultrasound has been a broad wide of clinical application for the acute cardiac injury, but little using both CT and MRI. The major problem is that inconvenient to perform the examination or make diagnosis, such as in a serious emergency condition, there is not enough time to accomplish a conventional check. As usual, the simplest method of examination was performed, or an experienced surgeon could make precise judgments in the degree of injury on the heart surgery during operation.

In our study, the acute MC is evaluated in pig model by DSCT. The dual source scanner adds a data acquisition system in the 64-slice CT, using two x-ray sources, two detectors at the same time, 2 direct cooling STRATON zero trillion UFC tube and two other ultra-fast detector row, which has an advantage of high temporal resolution [4]. The frame is magnetic levitation technology-driven rapid rotation to achieve the faster speed to scan, which can rotate a circle of just 0.33 s. The temporal resolution is 1/4 (82.5ms) of the rotation time in modality, faster than the heart rate. So that the image quality can not be affected by heart rate and breathing movement. The high-quality images rely on the contrast density of natural tissues, with higher temporal resolution and significantly lower radiation doses, making it the one-stop shopping preferred to the method of the heart and the great vessels, to improve the diagnostic accuracy and efficiency.

Many investigations have reported the animal model of impacting injury of the myocardium. There are two models: in vivo and in vitro, in which the vivo model can be divided into direct and indirect open-heart impact injury. There are many animals for cardiac injury such as rats, rabbits, dogs, pigs, etc [5]. The pig heart can illustrate the clinical and pathological cardiac contusion, because its physiological changes in the state of the heart and coronary circulation are rather close to those of the human beings [6], with well correlation between the clinical pathology and physiological issues of the blunt heart injury in the state, so there is a great advantage of the comparison with experimental samples.

The results suggest that pigs with severe MC immediately occurred descent of heart rate, followed by 2h-8h rising persistently after injury, then gradually recovered to normal level. No significant changes occurred in breathing. The studies reported that the heart rate was quite different for the MC of the rabbit and the dog, and always accompanied by tachycardia [7]. Authors speculate that the small animals have poor tolerance, adding to the interferential factors such as heart rate, fast breathing on its hemodynamic effects. It can result in obvious error in the measurement of left ventricular function due to the different animal sizes, less accurate injury impact site, and inconstant contusion position.

It had great changes in 2h when trauma happened, and some heart injury would be repaired by followed 2h.The parameters show that the left ventricular ejection fraction, fractional shortening rate and wall thickening before trauma were significantly different from at 4h after injury, compared with those in pre-trauma. The myocardial recovery was more obvious at 8h in trauma, indicating the decreased difference in left ventricular ejection fraction, fractional shortening rate and wall thickening rate than those in pre-trauma. Left ventricular shape change had been restored in 1 case after 8h. DSCT demonstrated no obvious abnormalities of the cardiac function in comparison with pre-trauma.

Abnormal cardiac function after trauma can lead to the cardiac conduction disorders. Patients with severe myocardial contusion, 33% to 73% of the serious arrhythmias may occur [8, 9]. In our study, one case of ventricular fibrillation occurred immediately after injury to ventricular asystole, then to death, 3 cases of premature ventricular bigeminy, 2 cases of type □ degree atrioventricular block, the other 3 pigs in various degrees of the supraventricular tachycardia. The conduction system disorder was not fully seen due to a relatively small number of samples and not enough observation.

In conclusion, the DSCT has advantages of the fast-speed, high quality of imagings, and convenient usage over ultrasound for MC to make a precise diagnosis in pig model. A new technical proposal has been expanded for further research on MC in clinical settings.

Acknowledgements

This work was funded by China Postdoctoral Science Foundation funded project (No.20090450866) and the planned science and technology project of Guangdong province, China (2011B080701019). This work was also supported by Guangzhou General Hospital of Guangzhou Military Command of PLA. The authors would like to thank the CT and US technologists, the department of radiology nursing staff, the department of cardiology staff physicians.

References

[1] Aksnes J, Foose E, Pilgram Larsen J, et al. Injuries to the heart. Injury 1993; 24(8): 545-548.

[2] Olsovsky MR, Wechsler AS, Topaz O. Cardiac trauma. diagnosis, management, and current therapy. Angiology 1997; 48(5): 423-432.
[3] Min JX, Zhu PF, Wang ZG. Patho-physiological changes after myocardial contusion. Chongqing Medical Science 1999; 28(6): 466.
[4] Achenbach S, Ropers D, Kuttner A, et al. Contrast-enhanced coronary artery visualization by dual-source CT-initial experience. Eur J Radiol 2006; 57(3): 331-335.
[5] Sabbah HN, Mohyi J, Hawkins ET, et al. Longitudinal evaluation of left ventricular performance in dogs following nonpenetrating cardiac trauma. J Trauma 1989; 29(2): 175-179.
[6] Ross J, Yang ZQ. Magnetic Resonance in medicine serial MRI evaluation of cardiac structure and function in mice after reperfused myocardial infarction. Radiology 2002; 47(6): 1158-1168.
[7] Du W, Min J, Zhu P, et al. Early changes and rules of cardiac function and hemodynamics in rabbits with experimental myocardial contusion. Chin J Traumatol 2002; 5(3): 161-164.
[8] Foil MB, Mackersie RC, Furst SR, et al. The asymptomatic patient with suspected myocardial contusion. Am J Surg, 1990; 160(6): 638-643.
[9] Shears LL, Hill RC, Timberlake GA, et al. Myocardial performance after contusion with concurrent hypovolemia. Ann Thorac Surg 1993; 55(4): 834-837.

Address for correspondence.

Dr Shan-xing Ou
General Hospital of Guangzhou military command of PLA
Liu Hua Road 111, Guangzhou, China, 510010
E-mail: oushanxing@sina.com