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在线全文

心脏磁共振特征追踪技术在高海拔地区扩张型心肌病的初步研究*

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【摘要】 **目的** 探讨心脏磁共振特征追踪（cardiovascular magnetic resonance feature tracking, CMR-FT）技术在高海拔地区扩张型心肌病（dilated cardiomyopathy, DCM）患者心肌应变中的初步应用。**方法** 回顾性搜集高海拔DCM患者（patients with DCM at high altitude, DCM-H）、平原DCM患者（patients with DCM at plain, DCM-P）、高海拔健康志愿者（healthy volunteers at high altitude, HV-H）、平原健康志愿者（healthy volunteers at high altitude, HV-P）各29例、27例、23例、24例。所有受试者均进行了3.0T MRI快速平衡稳态自由进动电影序列扫描。所获得的CMR图像使用cvi42后处理软件进行分析，获得左室心功能参数及心肌应变参数。**结果** DCM-H组左室舒张末容积和收缩末容积高于HV-H组，射血分数、每搏输出量低于HV-H组（所有P<0.01）。DCM-H组与DCM-P组心功能差异无统计学意义。与HV-H相比，DCM-H组整体径向、周向、纵向应变（%）（14.5±6.5 vs. 34.2±10.7; −11.1±4.4 vs. −19.9±2.8; −7.7±3.2 vs. −13.6±4.1）绝对值更低，差异有统计学意义（所有P<0.001）。DCM-H组比DCM-P组整体径向、周向、纵向应变绝对值（%）高（14.5±6.5 vs. 7.0±2.7; −11.1±4.4 vs. −5.4±2.2; −7.7±3.2 vs. −4.3±1.7; 所有P<0.01）。**结论** 高海拔DCM患者的心肌应变低于高海拔健康志愿者，高于平原DCM患者。CMR-FT可以定量评估高海拔地区DCM患者心肌收缩能力，在临床应用中具有较好的前景。

【关键词】 CMR-FT 扩张型心肌病 高海拔 心肌应变

Preliminary Study of Dilated Cardiomyopathy at a High Altitude Based on Cardiac Magnetic Resonance Feature Tracking

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[Abstract] **Objective** To investigate the application of cardiovascular magnetic resonance feature tracking (CMR-FT) in assessing myocardial strain in dilated cardiomyopathy (DCM) patients residing at high altitudes. **Methods** We retrospectively enrolled 29 DCM patients living at high altitudes (DCM-H), 27 DCM patients living in a low-altitude plain environment (DCM-P), 23 healthy volunteers living at a high altitude (HV-H), and 24 healthy volunteers living in a low-altitude plain environment (HV-P). All subjects underwent cine MRI scanning using a 3.0T rapid steady-state free precession sequence. The CMR images thus acquired were analyzed using cvi42, a post-processing software, to obtain left ventricular function and myocardial strain parameters. **Results** Compared with the HV-H group, the DCM-H group showed higher left ventricle end-diastolic volume (LVEDV) and left ventricle end-systolic volume (LVESV), and lower left ventricular ejection fraction (LVEF) and stroke volume (LVSV) (all P < 0.01). No significant difference was observed in cardiac function between the DCM-H and DCM-P groups (all P > 0.05). The absolute values of global radial strain (GRS), global circumferential strain (GCS), and global longitudinal strain (GLS) in the DCM-H group were lower than those in the HV-P group ([14.5 ± 6.5]% vs. [34.2 ± 10.7]%, [−11.1 ± 4.4]% vs. [−19.9 ± 2.8]%, and [−7.7 ± 3.2]% vs. [−13.6 ± 4.1]%, respectively), with the differences being statistically significant (all P < 0.001). The DCM-H group had higher absolute GRS, GCS, and GCS values than the DCM-P group did ([14.5 ± 6.5]% vs. [7.0 ± 2.7]%, [−11.1 ± 4.4]% vs.

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[−5.4 ± 2.2]%, and [−7.7 ± 3.2]% vs. [−4.3 ± 1.7]%, respectivley, all P < 0.01). **Conclusion** Myocardial strain in DCM patients living at a high altitude is lower than that in healthy volunteers living at a high altitude, but higher than that in DCM patients living in a low-altitude plain environment. CMR-FT can be used to quantitatively assess myocardial contractility in DCM patients living at a high altitude, showing promise for clinical application.

[Key words] CMR-FT Dilated cardiomyopathy High altitude Myocardial strain

扩张型心肌病(dilated cardiomyopathy, DCM)是一种以左心室或双心室扩张伴收缩功能障碍为特征的异质性心肌病，心肌纤维化是该病的常见组织病理学特征；临床表现包括心衰、心律失常、代谢异常、血栓栓塞和猝死[1-2]。心脏磁共振(cardiovascular magnetic resonance, CMR)组织分辨率高，能够通过多参数、多序列成像的方式评估出心脏功能和其组织特征[3-4]。其中，CMR特征追踪(CMR feature tracking, CMR-FT)技术可以评估DCM患者的心肌应变，了解患者心肌收缩功能，并预测患者最终结局[5-6]。高海拔人群长时间面临低氧、低气压、低温为特点的环境，机体通过代偿性低氧调节反应，对心脏结构产生影响[7-11]。目前，CMR-FT对DCM患者心肌应变的研究主要集中在低海拔患者，对于世居高海拔地区或移居高海拔地区人群的研究尚未见报道。本研究旨在通过CMR-FT评估高海拔DCM患者的心肌应变特征，比较高海拔DCM患者与低海拔DCM患者心肌应变特征的差异。

1 资料与方法

1.1 研究对象

根据世界卫生组织认定标准，海拔高于2 500 m即为高海拔地区。于本院(海拔约500 m)回顾性搜集2020年6月–2024年3月确诊的高海拔DCM患者(高于2 500 m, DCM patients living at a high altitude, DCM-H)、平原DCM患者(海拔约500 m; DCM patients living in low-altitude plain environment, DCM-P)各29例、27例。DCM患者纳入标准：①参考美国心脏协会、美国心脏病协会、欧洲心脏病协会诊断标准，即患者左心室舒张末容积(left ventricle end-diastolic volume, LVEDV)大于正常人2倍标准差，且左心室射血分数(left ventricular ejection fraction, LVEF)<50%[1, 12]；②患者进行CMR扫描前未接受DCM相关治疗。排除标准：①伴有缺血性心脏病、其他类型非缺血性心肌病、瓣膜病、先天性心脏病。②图像质量不能满足图像后处理的要求。同时搜集在这期间年龄、性别匹配的高海拔健康志愿者(healthy volunteers lving at a high altitude, HV-H)23例，平原健康志愿者(healthy volunteers living in low-altitude plain environment, HV-P)24例。健康志愿者无心脑血管疾病，且心电图、超声心动图、血压、血常规、胸部CT正常。本研究通过四川大学华西医院伦理委员会批准(2015年审304号)。

1.2 检查方法

所有受试者均在3.0T CMR(Magnetom Tim Trio, 西门子，德国)进行快速平衡稳态自由进动(steady-state free precession, SSFP)电影序列扫描。检查前准备包括去除金属异物、进行屏气训练。序列参数：重复时间为3.4 ms，回波时间为1.3 ms；翻转角度为50°；视野为300 mm×340 mm；矩阵大小为256×144；层厚为8 mm，层间距为0；带宽为100 kHz。通过扫描获得左心室两腔心(短轴和长轴)、三腔心、四腔心图像。

1.3 图像分析

两名具有五年以上经验的心脏影像学医师采用cvi42软件分析心功能及心肌应变。采用自动勾画功能勾勒心内膜及心外膜轮廓(图1)，必要时对轮廓进行手动校正，勾画图像包括短轴位、二腔心以及四腔心长轴位。经过软件处理获得心功能及心肌应变参数，包括LVEF、LVEDV、左心室收缩末容积(left ventricle end-systolic volume, LVESD)、左心室每搏输出量(left ventricle stroke volume, LVSV)和左心室整体径向应变(global radial strain, GRS)、周向应变(global circumferential strain, GCS)、纵向应变(global longitudinal strain, GLS)。

1.4 统计学方法

所有受试者数据均使用SPSS 22.0软件(IBM Corp, 美国)进行统计分析。正态性检验采用Shapiro-Wilk检验。符合正态分布的计量资料以$\bar{x} \pm s$表示，非正态分布的数据经对数转换呈正态分布后进行分析。方差齐则采用单因素方差分析比较DCM-H、DCM-P、HV-H、HV-P四组数据，若差异有统计学意义，则进一步采用Bonferroni检验进行DCM-H与DCM-P、DCM-H与HV-H、HV-H与HV-P两两比较。方差不齐则采用Welch's ANOVA比较四组差异，差异有统计学意义则通过Games-Howell检验进行两两比较。分类数据分析使用卡方检验。心功能与心肌应变之间的关系采用Pearson相关分析。P<0.05为差异有统计学意义。

2 结果

2.1 受试者基本资料

所有受试者的基本资料见表1。所有受试者性别、年

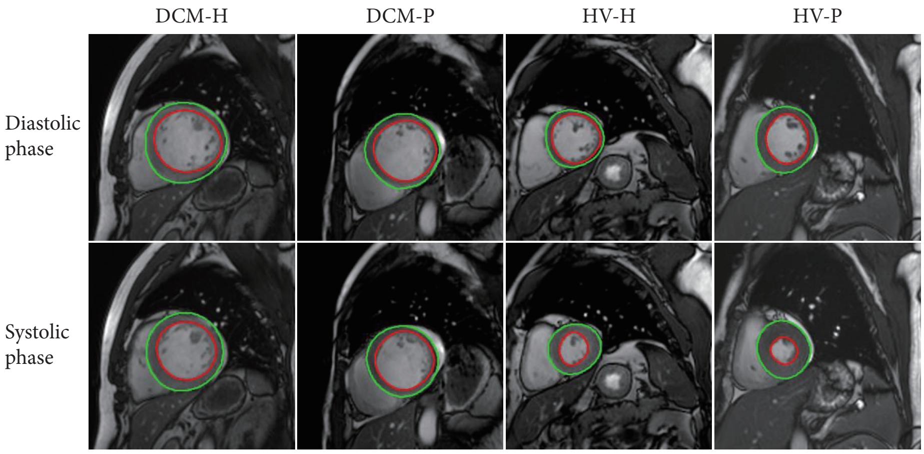

图 1 舒张期与收缩期CMR图像及心内外膜勾画

Fig 1 Diastolic and systolic CMR images and outlining of endocardium and epicardium

DCM-H: patient with dilated cardiomyopathy living at a high altitude; DCM-P: patient with dilated cardiomyopathy in low-altitude plain regions; HV-H: healthy volunteer living at a high altitude; HV-P: healthy volunteer in low-altitude plain regions. The green line traces the epicardium, and the red line marks the endocardium.

表 1　受试者基本资料

Table 1　Basic data of the subjects

Variable	DCM-H (n = 29)	DCM-P (n = 27)	HV-H (n = 23)	HV-P (n = 24)	P	F
Age/yr.	42.2 ± 13.2	44.2 ± 13.2	38.8 ± 10.9	44.3 ± 14.5	0.433	0.921
Male/case (%)	19 (65.5)	17 (63.0)	12 (52.2)	13 (54.2)	0.715	1.359
Body mass/kg	66.8 ± 16.0	66.9 ± 10.3	63.4 ± 15.0	66.6 ± 9.7	0.27	1.344
Height/cm	166.1 ± 7.2	164.6 ± 9.1	166.0 ± 10.7	163.0 ± 8.9	0.589	0.644
SBP/mmHg	112.0 ± 20.9$^{\#\#}$	111.5 ± 19.4	129.5 ± 6.8$^{\wedge}$	115.0 ± 14.9	< 0.001	14.365
DBP/mmHg	72.3 ± 15.6$^{\#\#}$	74.9 ± 11.8	84.8 ± 5.7$^{\wedge\wedge\wedge}$	76.0 ± 9.1	0.001	12.000
HR/min^{-1}	77.7 ± 15.6$^{*,\#\#}$	91.5 ± 19.3	91.8 ± 8.6	85.3 ± 9.1	0.001	6.245

SBP: systolic blood pressure; DBP: diastolic blood pressure; HR: heart rate; the other abbreviations are explained in the notes to Fig 1. * P < 0.05, vs. DCM-P; $^{\#\#}$ P < 0.01, vs. HV-H; $^{\wedge}$ P < 0.05, $^{\wedge\wedge\wedge}$ P < 0.001, vs. HV-P. The data are expressed as $\bar{x} \pm s$ except those for sex. 1 mmHg = 0.133 kPa. All the variables are analyzed by Welch's test except for body mass, which is analyzed by one-way ANOVA.

龄、体质量、身高差异无统计学意义(所有P>0.05)。DCM-H组心率低于DCM-P组(P<0.05)。DCM-H组的收缩压、舒张压、心率比HV-H组低(所有P<0.01)。HV-H组收缩压和舒张压比HV-P组高(P=0.01)。

2.2　受试者心功能参数和心肌应变

所有受试者的心功能及心肌应变参数见表2、表3。相比于HV-H组，DCM-H组LVEDV和LVESV更高，且LVEF、LVSV更低(所有P<0.01)。DCM-H组与DCM-P组心功能相似(所有P>0.05)。HV-H组对比HV-P组，LVEDV、LVESV、LVSV均更高(所有P<0.001)，而LVEF的差异无统计学意义(P>0.05)。DCM-H组对比HV-H组，GRS、GCS、GLS绝对值均更低(所有P<0.001)。DCM-H组比DCM-P组GRS、GCS、GLS绝对值更高(所有P<0.01)。HV-H组GRS、GCS绝对值均比HV-P组低(两者P<0.05)。各组心肌应变代表图见图2。

2.3　高海拔DCM患者心肌应变与心功能参数的关系

见表4。LVEF、LVSV与GRS、GCS绝对值呈正相关。LVSV与GLS绝对值呈正相关。

表 2　受试者心功能参数

Table 2　Cardiac function parameters of the subjects

Parameter	DCM-H (n = 29)	DCM-P (n = 27)	HV-H (n = 23)	HV-P (n = 24)	P	F
LVEF/%	25.5 ± 11.7$^{\#\#\#}$	18.4 ± 3.8	61.2 ± 6.0	64.3 ± 5.2	< 0.001	300.8
LVEDV/mL	303.2 ± 96.8$^{\#\#\#}$	329.1 ± 43.7	145.6 ± 34$^{\wedge\wedge\wedge}$	85.1 ± 20.3	< 0.001	268.7
LVESV/mL	231.6 ± 101.9$^{\#\#\#}$	268.9 ± 34.7	59.3 ± 25.7$^{\wedge\wedge\wedge}$	32.3 ± 11.4	< 0.001	327.5
LVSV/mL	71.6 ± 18.2$^{\#\#}$	60.3 ± 21.7	86.3 ± 13.2$^{\wedge\wedge\wedge}$	52.8 ± 14.6	< 0.001	26.8

LVEF: left ventricular ejection fraction; LVEDV: left ventricle end-diastolic volume; LVESV: left ventricle end-systolic volume; LVSV: left ventricle stroke volume. The other abbreviations are explained in the notes to Fig 1. $^{\#\#}$ P < 0.01, $^{\#\#\#}$ P < 0.001, vs. HV-H; $^{\wedge\wedge\wedge}$ P < 0.001, vs. HV-P. The data are expressed as $\bar{x} \pm s$. All parameters are analyzed by Welch's test.

表 3　受试者心肌应变参数

Table 3　Myocardial strain of parameters the subjects

Parameter	DCM-H (n = 29)	DCM-P (n = 27)	HV-H (n = 23)	HV-P (n = 24)	P	F
GRS/%	$14.5 \pm 6.5^{***,\#\#\#}$	7.0 ± 2.7	$34.2 \pm 10.7^{\wedge}$	41.0 ± 6.5	< 0.001	153
GCS/%	$-11.1 \pm 4.4^{***,\#\#\#}$	-5.4 ± 2.2	$-19.9 \pm 2.8^{\wedge\wedge\wedge}$	-24.7 ± 2.0	< 0.001	185.6
GLS/%	$-7.7 \pm 3.2^{**,\#\#\#}$	-4.3 ± 1.7	-13.6 ± 4.1	-15.8 ± 1.5	< 0.001	101.4

GRS: global radial strain; GCS: global circumferential strain; GLS: global longitudinal strain. The other abbreviations are explained in the notes to Fig 1. ** $P < 0.01$, *** $P < 0.05$, vs. DCM-P; $^{\#\#\#}$ $P < 0.001$, vs. HV-H; $^{\wedge}$ $P < 0.05$, $^{\wedge\wedge\wedge}$ $P < 0.001$, vs. HV-P. The data are expressed as $\bar{x} \pm s$. All parameters are analyzed by Welch's test.

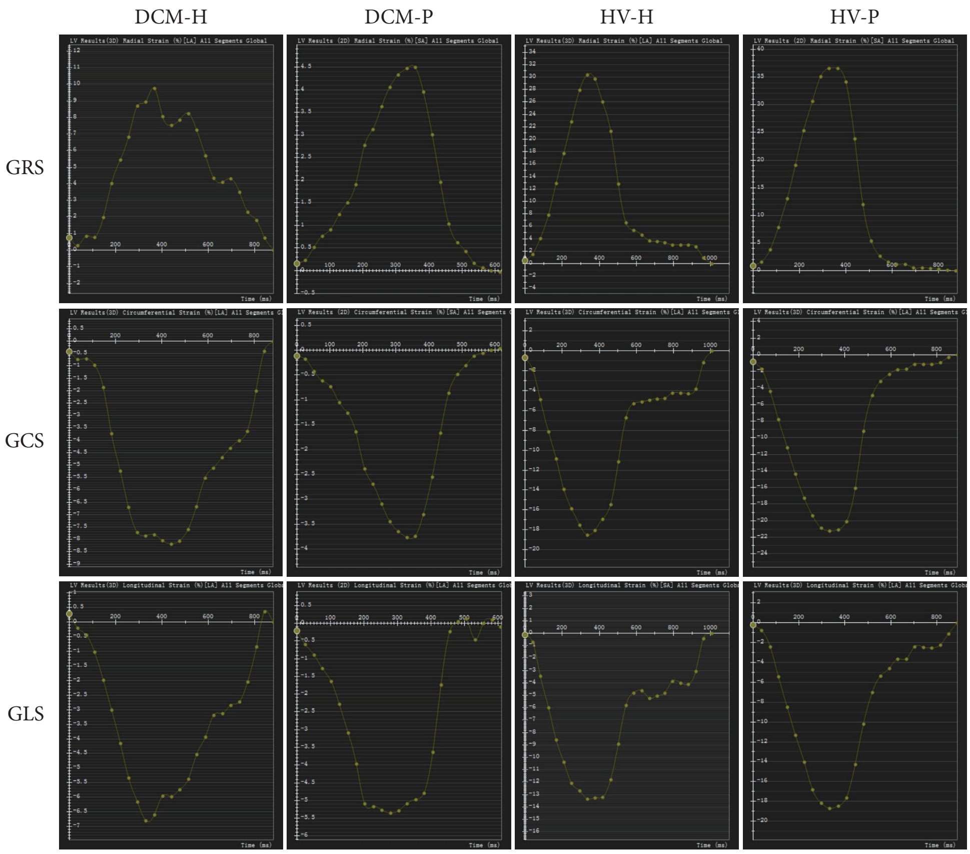

图 2 代表性心肌应变图

Fig 2 Representative images of myocardial strain

All abbreviations are explained in the notes to Fig 1 and Table 3.

表 4　高海拔DCM患者心功能与心肌应变的相关性

Table 4　Relationship between cardiac function and myocardial strain in patients with DCM at a high altitude

Parameter	GRS/% (n = 29)		GCS/% (n = 29)		GLS/% (n = 29)	
	r	P	r	P	r	P
LVEF/%	0.533	0.003	0.486	0.009	0.319	0.098
LVEDV/mL	−0.237	0.225	−0.119	0.546	−0.011	0.954
LVESV/mL	−0.347	0.070	−0.225	0.249	−0.101	0.610
LVSV/mL	0.558	0.002	0.536	0.003	0.452	0.016

All abbreviations are explained in the notes to Table 2 and Table 3.

3　讨论

DCM的临床病程具有高度异质性,从无明显临床症状到严重心力衰竭,甚至心脏猝死,左心室舒张收缩功能障碍是DCM的主要病理生理改变[13-15]。DCM不良重构主要表现为左室壁变薄和扩张、左室充盈压力增加、心室顺应性降低[5]。已有研究发现DCM患者LVEDV和LVESV均增加,而LVEF降低[16-17],但高海拔DCM患者与平原DCM患者二者是否存在差异未见文献报道。本研究对比高海拔DCM患者与高海拔志愿者的心功能参数,发现高海拔DCM患者LVEDV、LVESV高于健康志愿者,

LVEF、LVSV低于健康志愿者,与平原DCM结果一致。

对于海拔2 500 m以上的高海拔地区,低压低氧导致肺泡氧分压及肺静脉内血氧分压下降,机体器官、组织、细胞水平获得的氧气均减少,人体将通过神经及体液调节氧气供需平衡[18-20]。长期居住在高海拔地区的人群通过代偿性低氧调节,逐步恢复机体稳态,维持其生存能力,最终适应高海拔环境[8, 21-22]。李慧兰等[23]发现高海拔急下平原的受试者比世居平原受试者的LVEDV、LVESV高,本研究在平原检查的高海拔健康志愿者LVEDV、LVESV也高于世居平原的健康志愿者。但是高海拔DCM患者心功能与平原DCM患者没有明显差异,这可能与机体的长期低压低氧适应性反应有关。

CMR-FT技术在测量心肌应变中具有广泛的临床应用前景。这种方法不需要进行额外序列的扫描,使用常规电影CMR图像,经过后处理即可获得心肌应变,易于临床实践中应用[24-25]。既往研究已证实了CMR-FT的可行性和有效性,多个应变参数显示了对于DCM患者的诊断价值[26-27]。有学者发现DCM主要累及心肌的中层和外层,表现为周向心肌应变的降低[6, 28],本研究与既往研究一致,高海拔DCM患者的GCS比高海拔健康志愿者低。此外,既往研究发现不仅GCS降低,GRS、GLS也降低[16-17],本研究也发现高海拔DCM患者的GRS和GLS均降低。本研究还发现高海拔健康志愿者的GRS、GCS均比平原健康志愿者低,提示高海拔低压低氧环境下心肌应变可能降低。值得一提的是高海拔DCM患者的GRS、GCS、GLS反而比平原DCM患者高,表明高海拔DCM患者心肌应变的改变可能比平原DCM小,其中原因有待于进一步研究,可能与心脏在长期低压低氧环境下,其心肌耐受性更强有关系。虽然高海拔DCM患者心肌应变比平原DCM患者改变小,且心肌应变与心功能成正比,但是最终二者的心功能无差异,说明心肌应变比心功能更能显示高海拔地区与平原地区的差异,需要进一步通过大样本临床研究验证和基础研究来探究其原理。

本研究存在以下不足:第一,高海拔地区患者样本量较小,今后需要长期且更大的样本量进一步验证相关结果。第二,本研究比较了高海拔DCM患者与平原DCM患者心肌应变的差异,作为回顾性研究,没有办法通过自身对照,对高海拔DCM、平原DCM患者生病前后心功能及心肌应变的变化进行比较,今后需要前瞻性研究进一步比较。第三,本研究虽然匹配了年龄、性别等因素,但仍需进一步研究其他因素对结果的影响。且高海拔DCM与平原DCM心肌应变存在差异,原因尚不明确,需要更深入地研究其存在的机制。第四,CMR-FT技术依赖于不同厂家的磁共振、不同的第三方后处理软件,结果的一致性需要指南和共识声明明确参考标准。

综上所述,本研究显示CMR-FT能够定量评估高海拔DCM患者的心肌应变,发现高海拔地区DCM患者与平原DCM患者心肌应变有差异,为临床个性化治疗DCM患者,改善患者预后提供影像学依据。

* * *

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