行政院國家科學委員會補助專題研究計畫成果報告

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※計畫名稱：心室外形與其出口大動脈分枝型態的※
※　　　　　關聯及其功能性含意　　　　　　　※
※　　　　　The Correlation Between Ventricular ※
※　　　　　Shape and Branching Pattern of its ※
※　　　　　Outgoing Great Artery and Their ※
※　　　　　Functional Implications ※
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計畫類別：☑個別型計畫　　□整合型計畫

計畫編號：NSC89－2314－B－002－283

執行期間：89 年 8 月 1 日至 90 年 12 月 31 日

計畫主持人：邱英世

共同主持人：陳世杰

王主科

本成果報告包括以下應繳交之附件：

□赴國外出差或研習心得報告一份

□赴大陸地區出差或研習心得報告一份

□出席國際學術會議心得報告及發表之論文各一份

□國際合作研究計畫國外研究報告書一份

執行單位：國立台灣大學醫學院 外科

中 華 民 國 91 年 3 月 31 日

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主持人：邱英世 國立台灣大學醫學院 外科
共同主持人：陳世杰/王主科 國立台灣大學醫學院 放射科/小兒科

一、中文摘要

大動脈完全轉位在過去半世紀以來的外科治療史發現右心室無法取代左心室做為全身循環的幫浦心室。但是為什麼右心室長成梯形而左心室呈梨形的功能性含意一直未被提出。我們在本計畫以核磁共振做研究來推論心室外形與其出口動脈分枝型態之相關性。

我們以核磁共振造影進行十名正常成人之心臟顯影，採用未飽和磁場脈衝外加在梯形右心室下緣之兩個銳角，並定量在左右肺動脈橫截面呈現之未飽和磁場量。本研究發現心室外形與其出口動脈分枝型態有關聯。了解心室外形之功能性含意有助於判斷矯正型大動脈轉位之病人是否應該接受雙轉換手術；對右心室已轉變成左心室外形且三尖瓣功能良好者施行傳統矯正手術即可。

關鍵詞：梯形右心室，梨形左心室，肺動脈幹提早分枝，主動脈較晚分枝，大動脈完全轉位。

Abstract

Throughout the surgical history to repair transposition of the great arteries in the past half-century, human has learned that the right ventricle cannot replace the left ventricle as a systemic pumping chamber. The shape of normal right ventricle is totally different from that of left ventricle, trapezoid of the former versus pear-form of the latter. Yet the functional implications of the shape were seldom explained in the past. The pulmonary trunk branches early into right and left pulmonary arteries. While the relatively late-branching of the aorta dictates its pumping chamber to become a pear-shaped left ventricle. We carried out a magnetic resonance imaging study on 10 normal persons, to see whether left lower vertex of the trapezoid right ventricle sends its blood into lower right pulmonary artery, while relatively higher right lower vertex into higher left pulmonary artery. The results showed the shape of ventricles is related with its outgoing arterial branching pattern. This inference is helpful to judge those patients with congenitally corrected transposition is justified to undergo double switch operation according to the shape of ventricles, i.e. those with incomplete transition.

Keywords: trapezoid right ventricle, pear-form left ventricle, early branching pulmonary trunk, relatively late-branching aorta, and complete transposition of the great arteries.

二、Background & Purpose

Throughout the surgical history to repair transposition of the great arteries in the past half-century, human has learned that right ventricle cannot replace the left ventricle (LV) as a systemic pumping chamber [1-3]. At present, arterial switch operation has become the repair of choice for transposition of the great arteries (TGA) with or without ventricular septal defect [1,4]. Yet in certain cases done properly, those with the Mustard or Senning operation has proved to have excellent results [5-8]. For congenitally corrected transposition, conventional repair or anatomical repair (double switch) remained in debate [9-11]. The ventricles must have adapted themselves to an unnatural role in cases survived after non-anatomical repair. The shape of normal right ventricle (RV) is totally different from that of LV, trapezoid of the former versus pear-form of the latter [12]. Yet the functional implication of the ventricular shape was seldom explained in the past. The pulmonary trunk branches early into right and left pulmonary arteries. While the relatively late-branching of the aorta dictates its pumping chamber to become a pear-shaped LV. In an effort to understand the necessity of the RV to send the venous blood to each lung through the bilateral pulmonary arteries dictates the shape of RV to be trapezoid, we carried out a magnetic resonance imaging study on 10 normal human.

三、Methods

A 1.5-T Simens Magnetom Vision System (Simens AG, Erlanger, Germany), with a 25 mT/m maximum gradient strength and a minimum gradient rise time of 6oo us was used. All had normal sinus rhythm and was examined in a body phased-array coil using prospective electrocardiographic triggering. For localization, T1-weighted spin echo sequences in the transverse, coronal and sagittal planes were performed. Sections with perpendicular to the flow direction of the left pulmonary artery (LPA) and right pulmonary artery (RPA) were simultaneously examined by a cine-MRI gradient echo sequence. The repetition time was 45 msec, echo time was 7 msec and flip angle was 40 degrees. Only 90% of a cardiac cycle was measured due to the limitation of the scanner. The matrix was 168 by 256, field of view was 289 by 330, and slice thickness10 mm. No pre-saturation pulse cine-MRI gradient echo sequence was performed first for the baseline and control data. Then, a pre-saturation pulse (virtually black due) with linear band of 50 mm width was created on the apex of the RV (Figure 1).

For quantitative flow analysis, we used a post-processing package provided by the manufacturer with the following procedure: positioning a region-of-interest (ROI) that covering the whole area of the RPA and LPA, repositioning the ROI on each images in different phases, calculation of mean inside the ROI versus time. We measured both RPA and LPA twice and used the average data for further statistical analysis. In order to get signal change of bilateral pulmonary arteries after use of virtual due, signal in the cross section of each PA at the same cardiac cycle without pre-saturation minus that with ones. The positive data indicated there had been virtual black dye flowing through and lowering down the signal. In addition, because we had only pre-saturated the blood at the apex of the RV, this positive result means this flowing blood coming from the apex of the RV. Conversely, if it presented negative data, this represents the blood passing through this PA section was originating from the part other than apex. The fresh spin coming outside the field-of-view of examination bring the high signal intensity, because of never been excited, contributed the rise of the signal.

Non-linear mix effect model were applied to the data for statistical analysis. For each patient, variable number of cardiac cycles was recorded, and blood flow at right and left pulmonary artery were measured. The intensity of signal was used as dependent variable. According to the exploratory analysis, there are three stages of peak flow during a cycle. A function of time including mixture of three exponential functions is used to model the time pattern of the intensity recorded at each side of pulmonary artery. The overall flow volume can be characterized using the integration of the function.

四、Results

The areas under the curve of LPA and RPA in before and after virtual dye application are significantly different (Table 1). It shows RPA get more virtual dye (signal drop) from the RV apex than LPA.

Actually, there are three pulsated flow in one cardiac cycle (Figure 2). We analyze these three different waves of flow pattern as well as the baseline and find there is a significant difference ($p<0.05$) between bilateral pulmonary arteries that get the virtual dye (Table 2). Majority of the virtual dye from RV apex ran into RPA.

五、Discussion

From our data, we can say most of the virtual dye from RV apex will go into RPA. Conversely, we also can propose that most of the fresh unsaturated blood in the RV cavity beside apex run to LPA. By the preferential destinations of the blood in the RV different locations, due to the design for minimal energy lost during traveling through the RV, so the RV is shaped to be trapezoid. This finding will be very important for further design of strategies of surgical correction of those ventriculo-arterial anomalies. In order to maintain the trapezoid shape of the RV and pear-form of the LV (the most nature and less work loading), the 3D curve of the pulmonary arterial branches in relationship to the ascending aorta should be take into seriously consideration.

六、Self-Evaluation

The result of this one-year project revealed consistent with the original proposal. Investigators have established a good protocol to study the use of the virtual dye in the flow dynamic of heart by MRI. The expected goal has successfully achieved by demonstrating the significant difference of RV apex flow to LPA and RPA. The result of this study is clinically applicable. This information will provide a concept of the importance of the 3D curve of the pulmonary arterial tree to surgeon. Besides, the inference is helpful to judge those patients with congenitally corrected transposition is justified to undergo double switch operation according to the shape of ventricles, i.e. those with incomplete transition.

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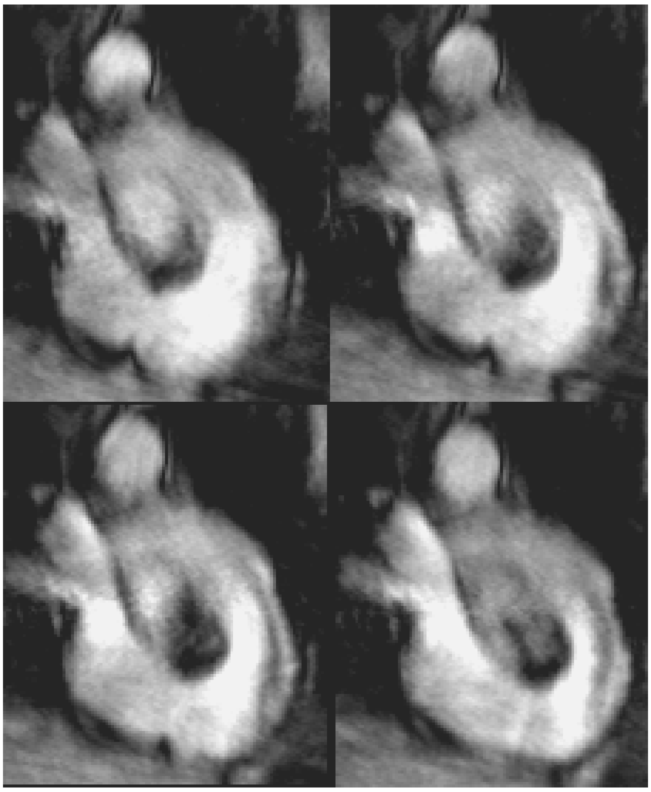

Figure 1. Virtual dye has been applied in the RV apex with seeing the direct flow of this black dye in the sequential images.

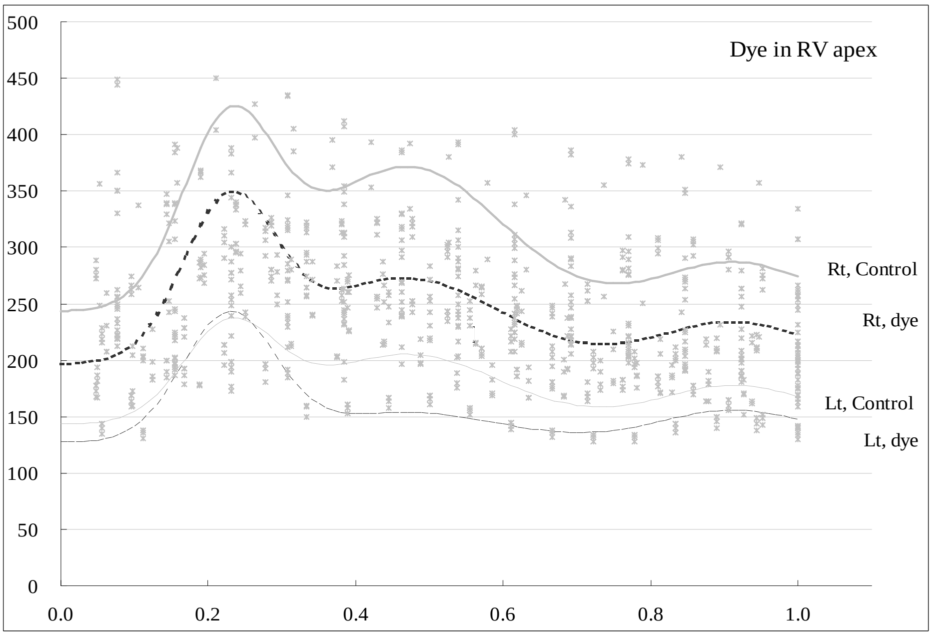

Figure 2. Plots of data of 10 normal subjects adjusted to one cardiac cycle.

Table 1. Area under the curves of LPA and RPA in before and after virtual dye be applied in the RV apex.

	LPA	Area drop		RPA	Area drop	
		value	Percentage		Value	Percentage
Control	185.1			321.4		
Dye (+)	160.6	24.5	13%	253.0	68.4	21%

Table 2. Models compared the control to virtual dye in the RV apex in bilateral pulmonary arteries.

	value	se	Z	p
LPA (-) min.	143.2	4.1	34.84	0.000
RPA (-) min.	100.0	5.0	19.96	0.000
LPA (+) min.	-27.6	5.1	-5.45	0.000
RPA (+) min.	-22.4	7.3	-3.05	0.002
LPA (-) max. 1	83.1	4.0	21.01	0.000
RPA (-) max. 1	75.5	5.3	14.14	0.000
LPA (+) max. 1	9.6	6.4	1.49	0.136
RPA (+) max. 1	-56.0	7.4	-7.52	0.000
m1	0.23	0.0	48.20	0.000
s1	0.09	0.0	25.70	0.000
LPA (-) max. 2	61.9	3.2	19.39	0.000
RPA (-) max. 2	66.3	3.6	18.28	0.000
LPA (+) max. 2	-11.3	3.8	-2.98	0.003
RPA (+) max. 2	-55.3	5.5	-10.00	0.000
m2	0.47	0.0	161.30	0.000
s2	0.18	0.0	30.96	0.000
LPA (-) max. 3	34.3	3.7	9.23	0.000
RPA (-) max. 3	9.1	4.1	2.22	0.026
LPA (+) max. 3	-4.2	3.8	-1.08	0.280
RPA (+) max. 3	-13.5	5.8	-2.34	0.019
m3	0.91	0.0	283.88	0.000
s3	0.15	0.0	17.75	0.000