

出國報告(出國類別：短修)

## 心臟血管影像之最新發展

服務機關：國防醫學院三軍總醫院

姓名職稱：張尊厚、主治醫師

派赴國家：美國

報告日期：99年3月15日

出國時間：98年3月1日至99年2月28日

## 摘要:

近年來心臟血管影像的進步，隨著造影技術的提升，日新月異，而本院雖有先進之儀器設備，但影像技術進步除了設備更新外，人員的經驗與知識的教育訓練，亦是同等重要。以下報告可區分如下：

### 一、心血管影像的臨床應用

#### 甲、電腦斷層 ( CT )

1. 冠狀動脈血管攝影 ( CT angiography of Coronary arteries )
2. 冠狀動脈血管鈣化指數計算 ( Coronary arteries calcium score )
3. 心律不整電燒灼術之術前評估 ( 左心房及肺靜脈血管攝影 )
4. 先天性心臟病的術前評估及術後追蹤
5. 主動脈瘤之術前評估及術後追蹤 ( 導管支架置放後追蹤 )

#### 乙、磁振造影 ( MRI )

1. 心臟結構與功能上之檢查
2. 心肌活性與心肌病之鑑別
3. 心肌灌注流影像
4. 先天性心臟病的術前評估及術後追蹤
5. 胸腔血管之磁振造影

### 二、成人型先天性心臟病

#### 甲、法洛氏四重症 ( Tetralogy of Fallot )

#### 乙、大動脈轉位症 ( Transposition of Great Arteries )

### 三、可發展重點

#### 甲、電腦斷層 ( CT )

#### 乙、磁振造影 ( MRI )

#### 丙、3D 醫學影像工作室

目次:

摘要	2
壹、目的	4
貳、過程	
一、地點背景	5
二、指導教授背景	5
三、修習重點	5
a. 心血管影像的臨床應用	
i. 電腦斷層 (CT)	
1. 多切面電腦斷層冠狀動脈攝影	5
2. 冠狀動脈血管鈣化指數計算	7
3. 心律不整電燒灼術之術前評	8
4. 先天性心臟病的術前評估及術後追蹤	9
5. 主動脈瘤之術前評估及術後追蹤	11
ii. 磁振造影 (MRI)	
1. 心臟結構與功能上之檢查	11
2. 心肌活性與心肌病之鑑別	12
3. 心肌灌注流影像	12
4. 先天性心臟病的術前評估及術後追蹤	12
5. 胸腔血管之磁振造影	12
b. 成人先天性心臟病	
i. 法洛氏四重症	17
ii. 大動脈轉位症	18
四、參與國際會議之海報張貼作	
a. 2009-10 NASCI Orlando (北美心臟影像醫學會年會, 在佛州奧蘭多舉行)	19
b. 2010-01 SCMR Phoenix (心血管磁振造影醫學會年會, 在亞歷桑那州鳳凰城舉行)	20
參、可發展重點:	
甲、電腦斷層 (CT)	21
乙、磁振造影 (MRI)	21
丙、3D 醫學影像工作室	21

## 壹. 目的:

近年來心臟血管影像的進步，隨造影技術的提升日新月異，而本院雖有先進之儀器設備，但影像技術進步除了設備更新外，人員的經驗與知識的教育訓練，亦是同等重要。於是本人出國短修目的，便是在於學習國外之經驗與長處，並進而回國後能有所發展。

## 貳. 過程：

### 一. 地點背景:

- a. 本人選擇了全美前十大醫學中心-費城賓州大學附屬教學醫院之放射線部心血管影像科 ( CardioVascular Imaging Division, Radiology, University of Pennsylvania Health System, Philadelphia), 作為學習研究之處. 該部門在教學研究上, 都有卓越之處; 影像設備大廠 SEIMENS 是該部門長期合作的對象, 所以不論 CT 或 MRI 都是當代最新的機型; 另外, 該單位也是美國放射線學院 (ACR) 認證可訓練心血管影像的專科教育單位, 除了每年的臨床專科訓練外, 也有短期(三個月)專科教育; 本人限於無美國醫師執照, 故謹以臨床訪問學者 (Visiting scholar) 身份, 參與其臨床專科教育。

### 二. 指導教授背景:

- a. Harold I. Litt MD-PhD. 是心血管影像科的主任, 其接受本人短期 (一年) 進修之申請, 所以是敝人形式上的指導教授. 他除了是北美放射線醫學會 (RSNA) 之會員外, 也是北美心臟血管影像學會 (NASCI) 及心臟血磁振造影學會 (SCMR) 的資深會員. 在這一年間, Dr. Litt 也指導敝人, 透過專題投稿方式, 參與上述之學會活動。
- b. Dr. Litt 目前的研究重心如下:
  - i. 心臟節律器的病人如何執行磁振造影
  - ii. 磁振造影下, 心肌灌注流影像的參數分析
  - iii. 動物實驗: 冠狀動脈血管硬化之機轉

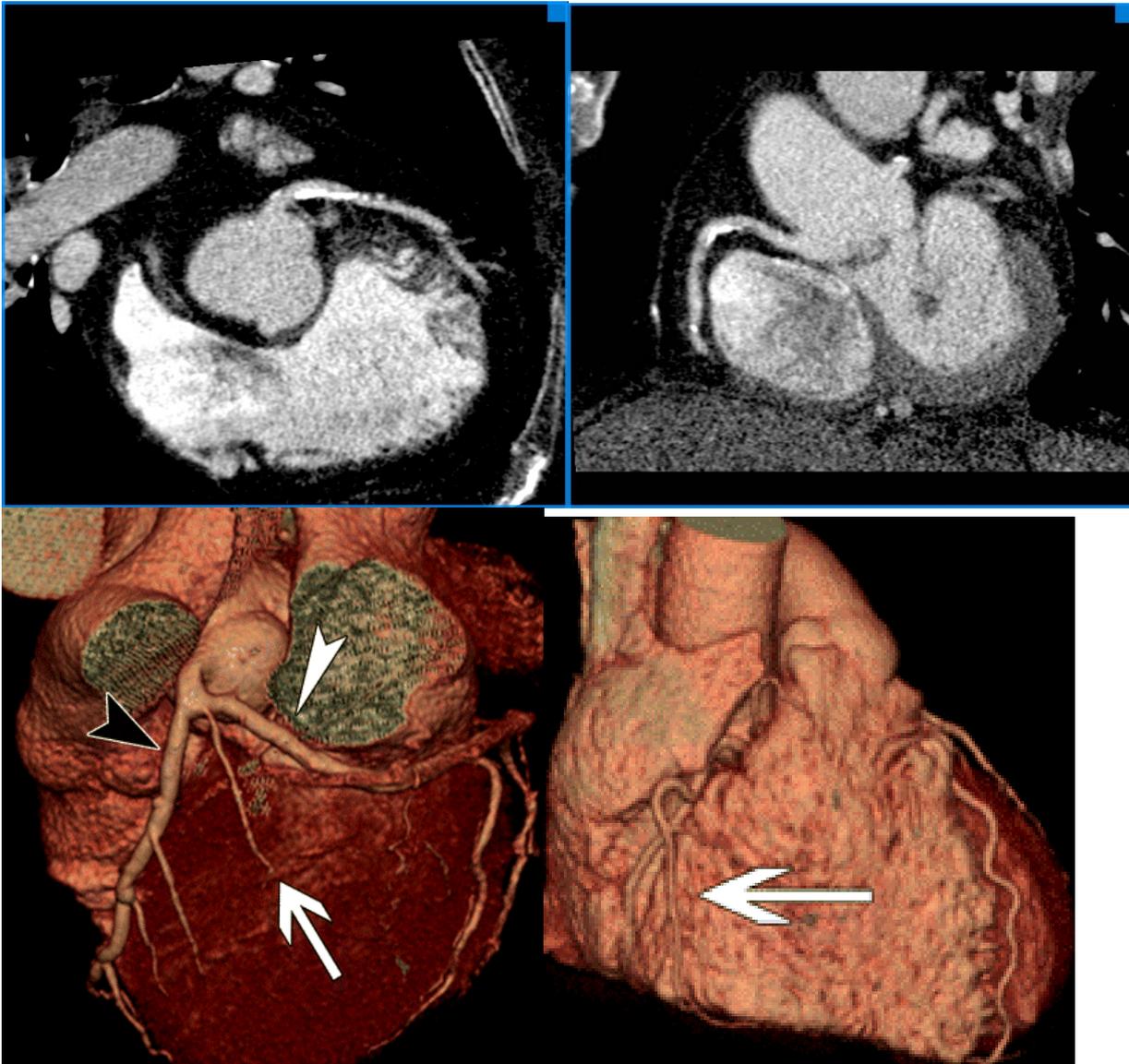
### 三. 修習重點:

- a. 心血管影像的臨床應用
  - i. 電腦斷層 (CT)
    1. 多切面電腦斷層冠狀動脈攝影 ( MDCT angiography of Coronary arteries )

#### \*\*\*前言\*\*\*

目前台灣醫藥及科技界對心臟血管疾病的診斷、治療和預防都竭盡最大的心力。其中一個廣受肯定的新方向是“多切面電腦斷層冠狀動脈攝影 (CTA)”，可以高速捕捉跳動中的心臟影像。受檢查者接受對比劑注射後，依照指令閉氣約 10 秒內，即可完成檢查；其診斷準確率幾乎與目前標準診斷方法“心導管檢查”相當—約可達 95%。其陰性預測率更在 95% 以上，這也表示當檢查結果如屬正常（陰性），絕大多數受檢者可不必再接受心導管攝影檢查。相較於心導管檢查，一般人的接受度也比較高，既可避免發生在心導管之 2% 的併發症和千分之一的死亡率，也可達到診斷之功效。

\*\*\*舉例\*\*\*



\*\*\*說明\*\*\*

在美國的醫藥生態，一切是以醫療保險業者規定的給付適應症為依據，符合適應症才能做檢查，所以臨床上大部分的個案皆因有急性胸痛的症狀，在急診室被安排“多切面電腦斷層冠狀動脈攝影”。

多切面電腦斷層冠狀動脈攝影要能達到高正確率的診斷，各方面要能善盡其事；硬體上，至少是 64 切面之電腦斷層機型(現今已有 320 切面)，再加上高功能的後處理工作站介面；軟體上，訓練有素的放射技術師—安全且正確引導病人完成檢查，更能正確有效地完成影像重組及後處理，之後，就得靠有知識及經驗的放射線專科醫師完成判讀診斷。這是一個團隊工作 (Team work)，專科醫師須負起指導教育團隊成員得工作。在 Penn Medicine(UPenn Hospital)的放射線部，是由心血管影像科 (C V I) 負責此工作。敝人即受教於該科，依敝人的觀察，C V I 有一 3D 醫學影像工作室，每日都有至少 2 名之專職放射師負責影像之後處理 (包括身體各部位之 3D 影像)。當然多切面電腦斷層冠狀動脈攝影是

其中的大宗，專職的工作，可提昇影像處理正確性及效率，這是相當的重要，3D 醫學影像工作室可先把影像判讀所需的 3D 影像與心功能的計算先完成，放射科醫師則可有效率地進行影像判讀診斷，當中，醫師若對影像數據有疑慮，醫師亦可自行在重作影像或與放射師討論，如此更能精進 3D 醫學影像工作室。

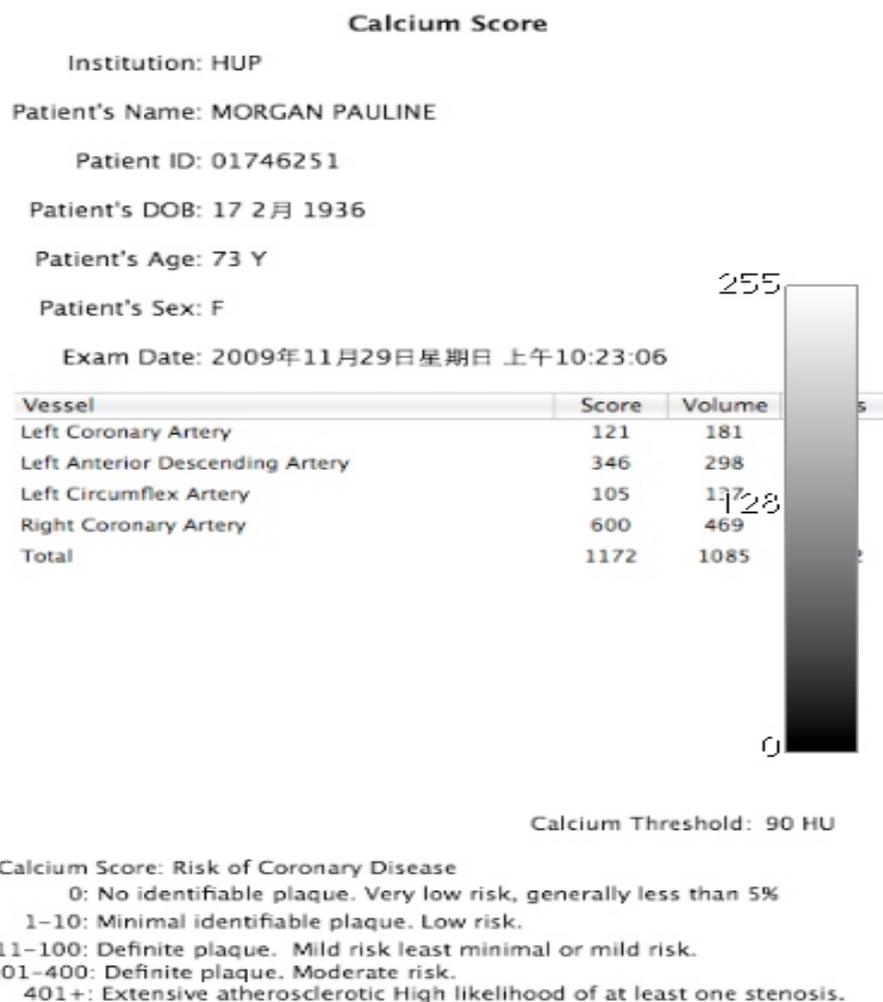
至於放射科醫師需不斷參與相關之繼續教育，碰上疑難處，不吝與同行之人討論，如此方能教學相長，在 C V I，每月會有一次的科會，除了例行的行政事物外，其他時間就是臨床及學術的討論了。

## 2. 冠狀動脈血管鈣化指數計算 (Coronary arteries calcium score)

### \*\*\*前言\*\*\*

冠狀動脈之鈣化現象，在動脈粥狀硬化早期就會發生，隨著時間鈣化會越來越多。文獻指出，血管狹窄程度與鈣化程度成正比，當冠狀動脈鈣化越多越嚴重，則發生冠心病的可能性就越大。使用電腦斷層心臟冠狀動脈鈣化分析，可以迅速瞭解冠狀動脈血管鈣化狀況，判斷未來心臟病發病的危險。傳統上預測冠心病的危險，是依據性別、年齡、總膽固醇值、高密度脂蛋白膽固醇值、吸菸及收縮血壓值。文獻指出，加入冠狀動脈鈣化分析，可以更精確的預測冠心病事件的發生。

### \*\*\*舉例\*\*\*



## General Guidelines for Interpretation of Calcium Scores

MDCT Calcium Score	Plaque burden & probability of significant CAD	Implications for CV risk	Recommendations
0-10	無法排除血管硬化之可能，但仍有少於5%機率罹患有血管阻塞問題	Very Low to Low	若無臨床症狀，則無需進一步處置，但仍無法完全排除非鈣化性造成之血管阻塞
11-100	符合輕度血管硬化之標準；少於20%會有發生血管阻塞問題	Moderate	建議服用低劑量之抗凝血劑與降血脂藥物；同等於兼具兩項危險因子的病患之治療
101-400	符合中度血管硬化之標準；有中度之可能性會有發生血管阻塞問題	Moderately High	對於已確認是冠心症之患者，積極使用降血脂藥物做預防，同時嚴格控制血糖值，血壓，並戒煙與服用低劑量之抗凝血劑

Calcium Score	Presence of Plaque
0	No evidence of plaque
1~10	Minimal evidence of plaque
11~100	Mild evidence of plaque
101~400	Moderate evidence of plaque
> 400	Extensive evidence of plaque

### \*\*\*說明\*\*\*

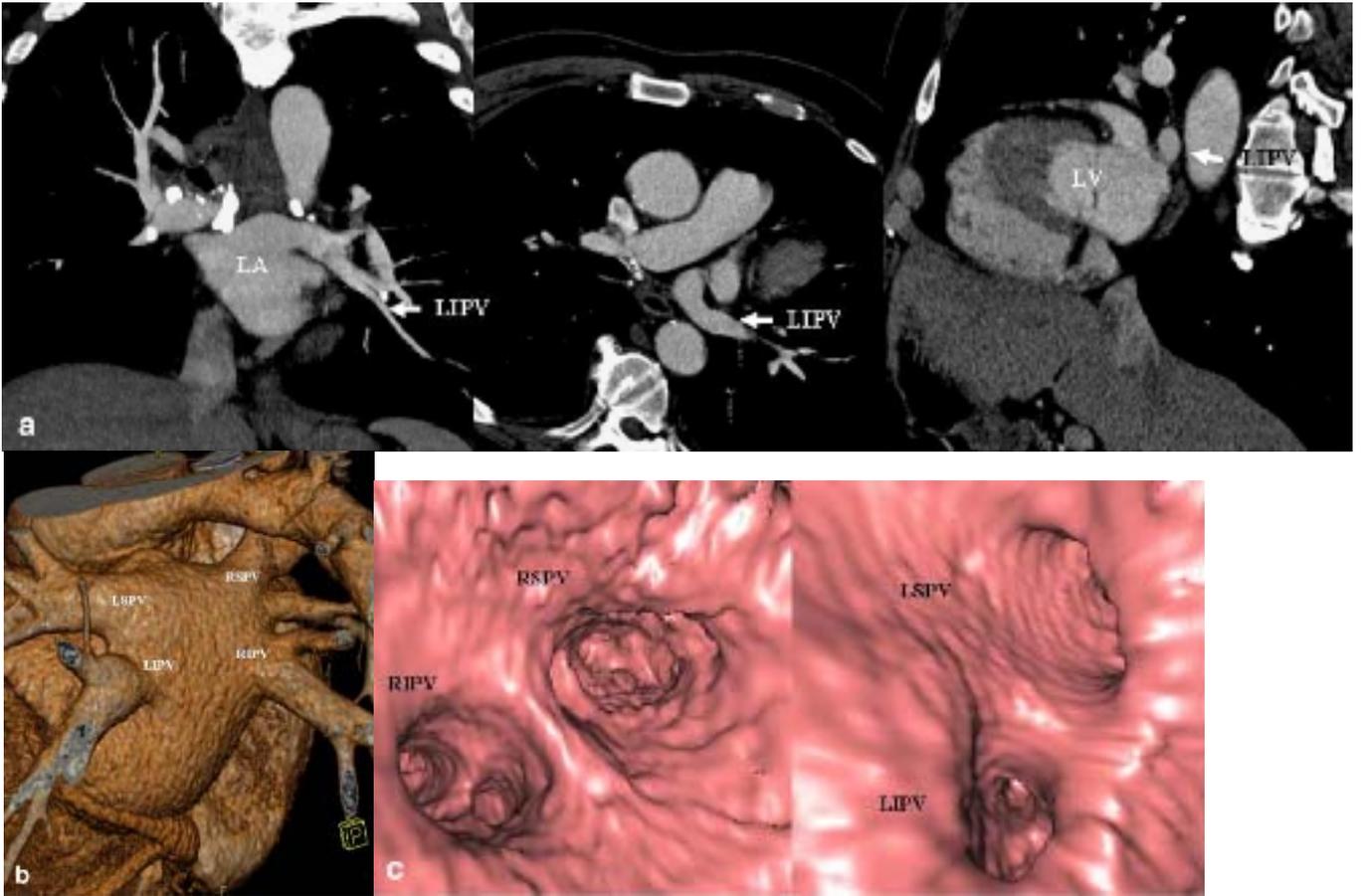
臨床實務上，急性冠狀血管症候群的診斷，可先評估其血管鈣化指數，之後在靜脈注射對比劑，完成多切面電腦斷層冠狀動脈攝影；這是最常見之臨床應用。其次，單做冠狀動脈血管鈣化指數的分析亦是另一種選擇，並依下表之建議做臨床診斷：

### 3. 心律不整電燒灼術之術前評估（左心房及肺靜脈血管攝影）

#### \*\*\*前言\*\*\*

經導管電氣燒灼術（簡稱電燒）是一種侵襲性的治療方式，它能截斷引起心律不整的不正常電路傳導途徑。在做電燒的過程中，醫師會插入一條特殊的導管線到心臟產生不正常電氣活動的地方。經導管線產生熱能，將非正常的傳導途徑破壞。例如：治療心房顫動，需對左心房及肺靜脈的解剖了解，方可完全及順利電燒不正常電氣活動的地方。而肺靜脈常發生一些正常變異，血管的會因人而異，左心房耳亦有相同情形，而多切面心臟電腦斷層正可提供完整清晰的3D影像，於電燒術前，正可提供很好的“路徑圖”（3D mapping）。

**\*\*\*舉例\*\*\***



**\*\*\*說明\*\*\***

在美國賓州費城的醫療保險給付的規定，也都支持這樣的治療路徑—術前影像評估，在 Penn Medicine，所有作電生理燒灼術的患者，都會作多切面心臟電腦斷層。其中完整的概念，可粗分三方面：電燒術前，術後（左心房和肺靜脈支解剖），與心臟節律器的置入前評估（冠狀竇靜脈的解剖位置）。當有肺靜脈的血管變異發生，影像能測量詳細的各分枝血管到心房匯入口的距離，可提升電燒術的安全與成功率；若術後於左心房耳有血栓形成，亦可及早發現。

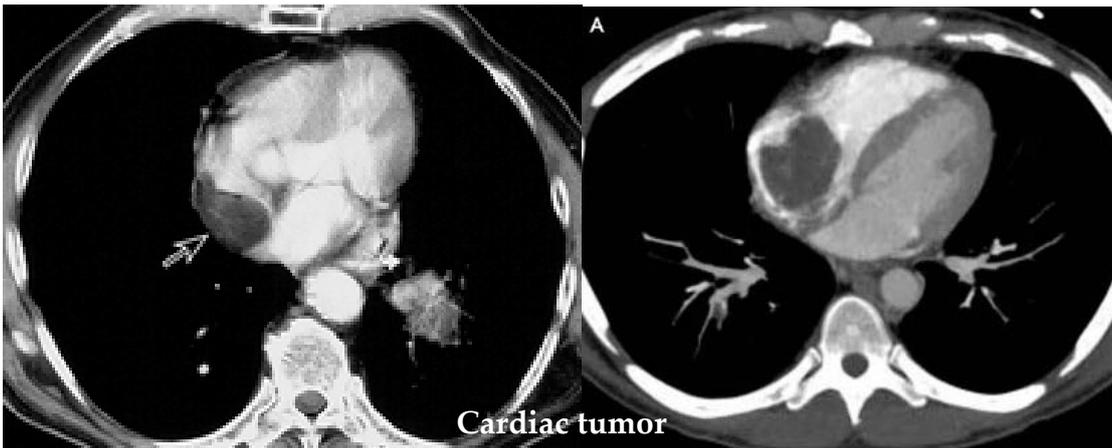
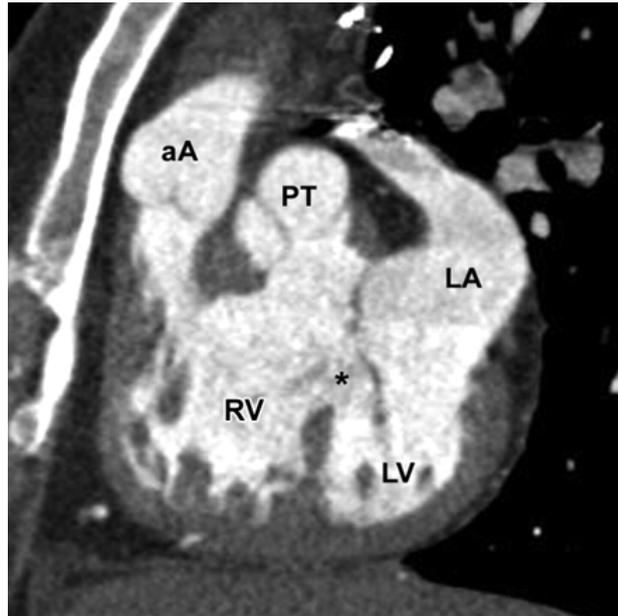
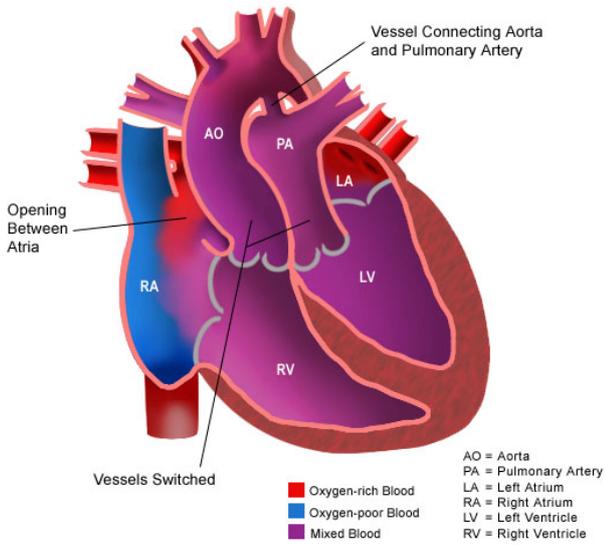
4. 先天性心臟病的術前評估及術後追蹤

**\*\*\*前言\*\*\***

多切面心臟電腦斷層可以掃描出清晰的心臟與血管之 3D 影像，所以可以用來評估心肌，冠狀動脈，肺靜脈血管，主動脈，心包膜和心臟腫瘤等。對於先天性結構異常的心臟，多切面心臟電腦斷層可迅速獲得完整清晰的影像來整斷。

\*\*\*舉例\*\*\*

Transposition of Great Arteries



\*\*\*說明\*\*\*

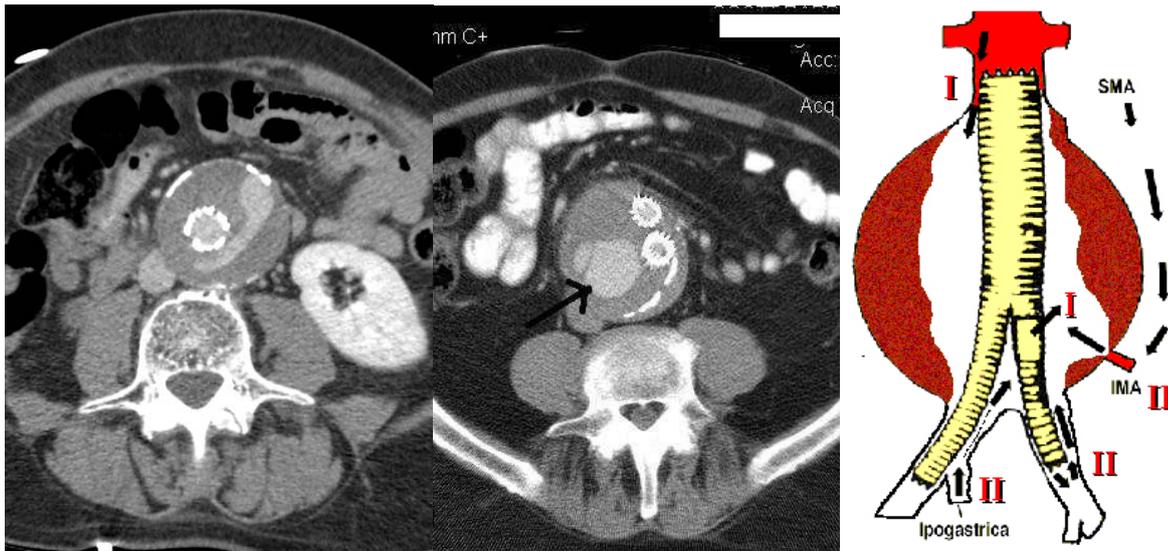
過去，診斷複雜的先天性心臟病，只能依賴心導管來診斷，過程徒增風險及難度，尤其小孩難度更高；現今，只要不到 10 秒鐘時間，即可掌握所有影像。在考量安全的輻射暴露下，且無對比劑過敏現象，多切面心臟電腦斷層幾乎無特殊禁忌症，尤其針對有心臟節律器置入患者，多切面心臟電腦斷層更是重要。

## 5. 主動脈瘤之術前評估及術後追蹤（導管支架置放後追蹤）

### \*\*\*前言\*\*\*

在血管外科的領域中，主動脈瘤是一個無明顯症狀且容易忽略，但是具生命威脅的主要疾病。隨著科技的進步，主動脈瘤的血管內支架治療手術正式引進國內。近年來新發展的主動脈瘤的血管內支架治療手術，相較於傳統開腹主動脈瘤手術而言，其安全性、侵襲性和術後恢復都有顯著的改善。倘若經過精密且正確的術前影像評估檢查，有一大部分的主動脈瘤患者是適合用低襲性血管內支架手術來治療的。

### \*\*\*舉例\*\*\*



### \*\*\*說明\*\*\*

隨著主動脈瘤的血管內支架治療手術日益普及，術後追蹤越重要。常見之術後病發症如支架滲漏，位移與血栓堵塞等。多切面電腦斷層可以完整呈現各樣的3D血管影像，一但有併發症形成，可及早偵測出並接受進一步處置。

- ii. **磁共振造影 (MRI):** 評估心臟收縮功能、包括心輸出量與心壁運動、心肌厚度、心肌存活造影、心臟灌流檢查。

### 1. 心臟結構與功能上之檢查

#### \*\*\*說明\*\*\*

磁共振造影的技術，可以針對心臟肌肉與瓣膜做精確的定量分析。不但可以測得心臟大小，也可以精準的計算心臟收縮力。利用其對組織分類有優於超音波的表現，一些心病變、心內腫瘤都可以透過這項檢查而得知。

## 2. 心肌活性與心肌病之鑑別

### \*\*\*說明\*\*\*

利用延後顯影(delayed enhancement)的技術，可以鑑別心肌活性，心肌纖維化結痂的地方，會有顯著之延後顯影；進而得知：接通血管是否對心肌功能的恢復是否有幫助。

## 3. 心肌灌注流影像

### \*\*\*說明\*\*\*

心肌灌注流影像，傳統上是利用核子醫學的技術，將有放射性物質(通常是 Thallium 201)注入體內，再以運動或藥物刺激心跳，得到一組心肌攝影的影像，在休息四小時後再取得一組影像；將兩組影像相比對則可得到心肌是否有缺少血液灌流的區域。而磁振造影的技術，亦可以類似方式，當對比劑注射後，在心肌不同部位迅速截取影像，故可獲得動態之灌注流影像，灌注缺損處即是病灶之所在。

## 4. 先天性心臟病的術前評估及術後追蹤

### \*\*\*說明\*\*\*

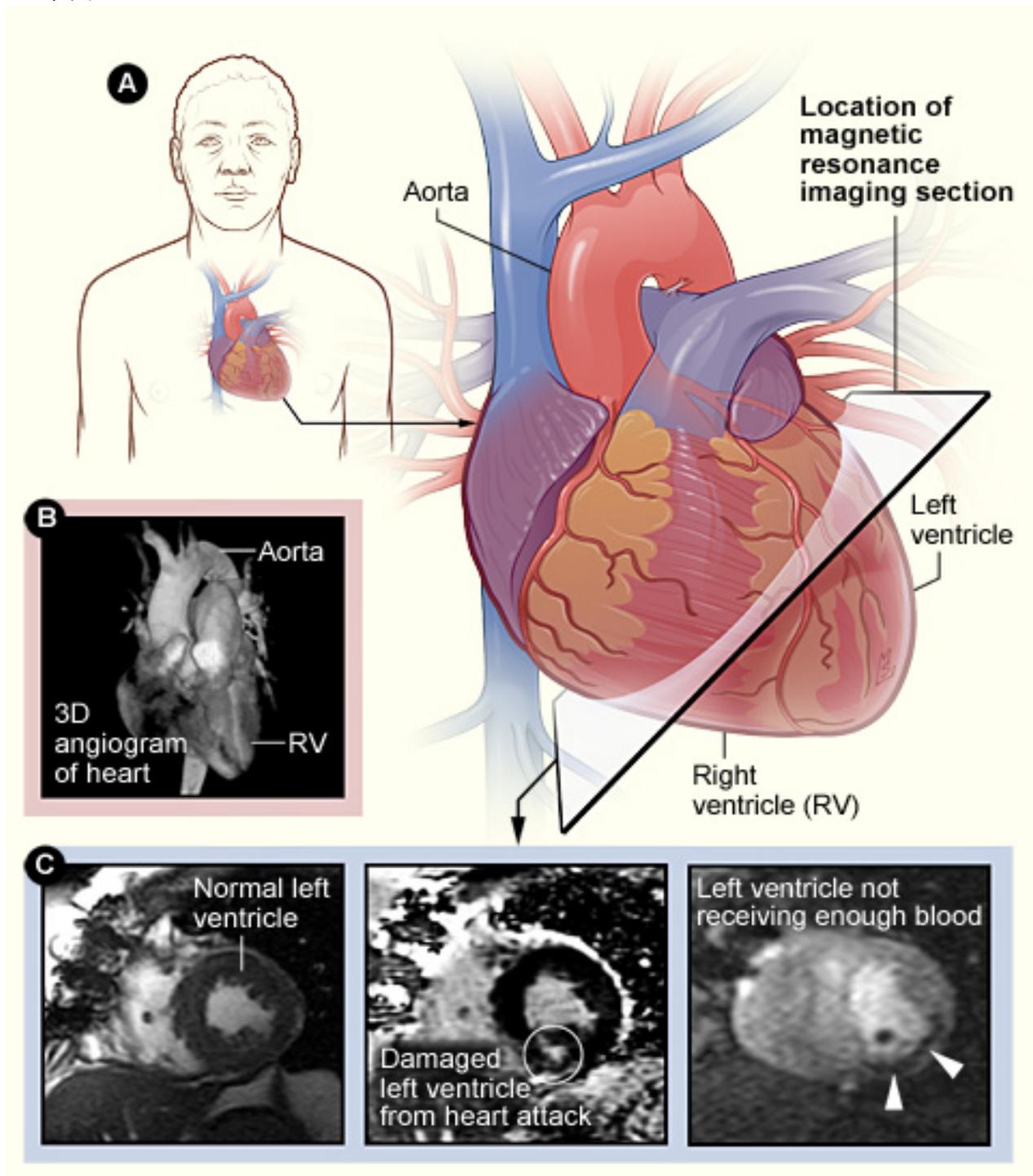
磁振造影沒有輻射暴露的隱憂，更可以獲取心肌活性與功能上的資料，所以，先天性心臟病的術前評估及術後追蹤，是以磁振造影為統一標準（這類病患終其一生接需依賴影像追蹤，磁振造影有優於超音波的表現）。

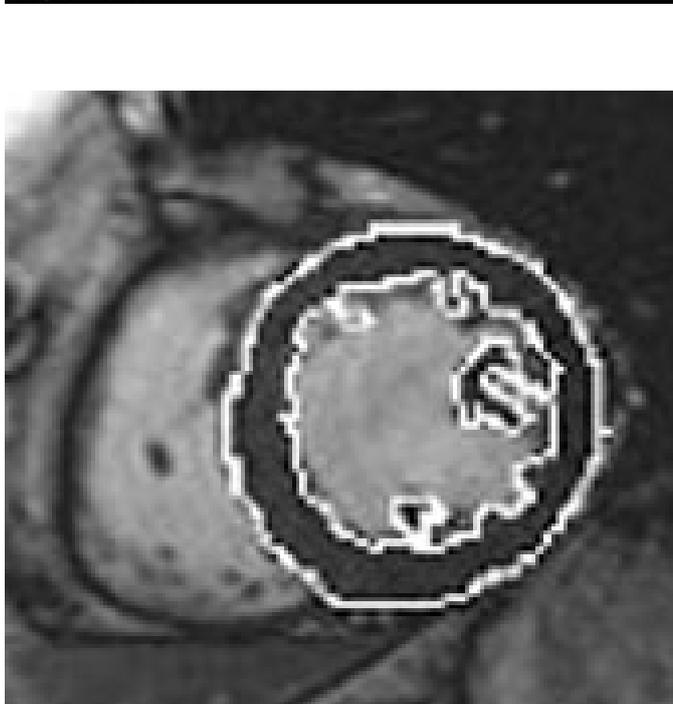
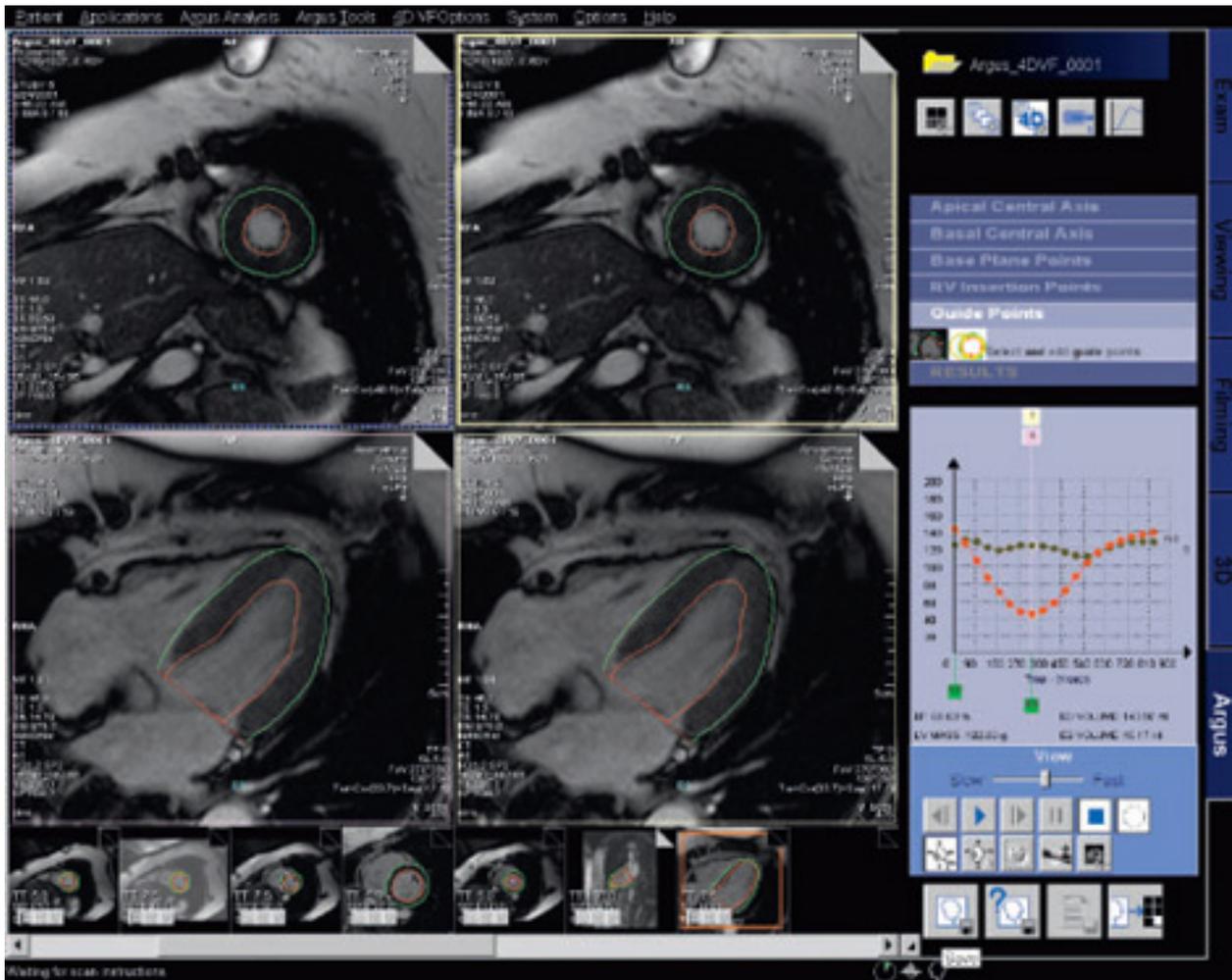
## 5. 胸腔血管之 磁振造影

### \*\*\*說明\*\*\*

舉凡多切面電腦斷層血管攝影能執行者，都也可以磁振造影來做，其中之差異在於：磁振造影還可以作血流速度與壓力差值的計算，而多切面電腦斷層血管攝影則不行。

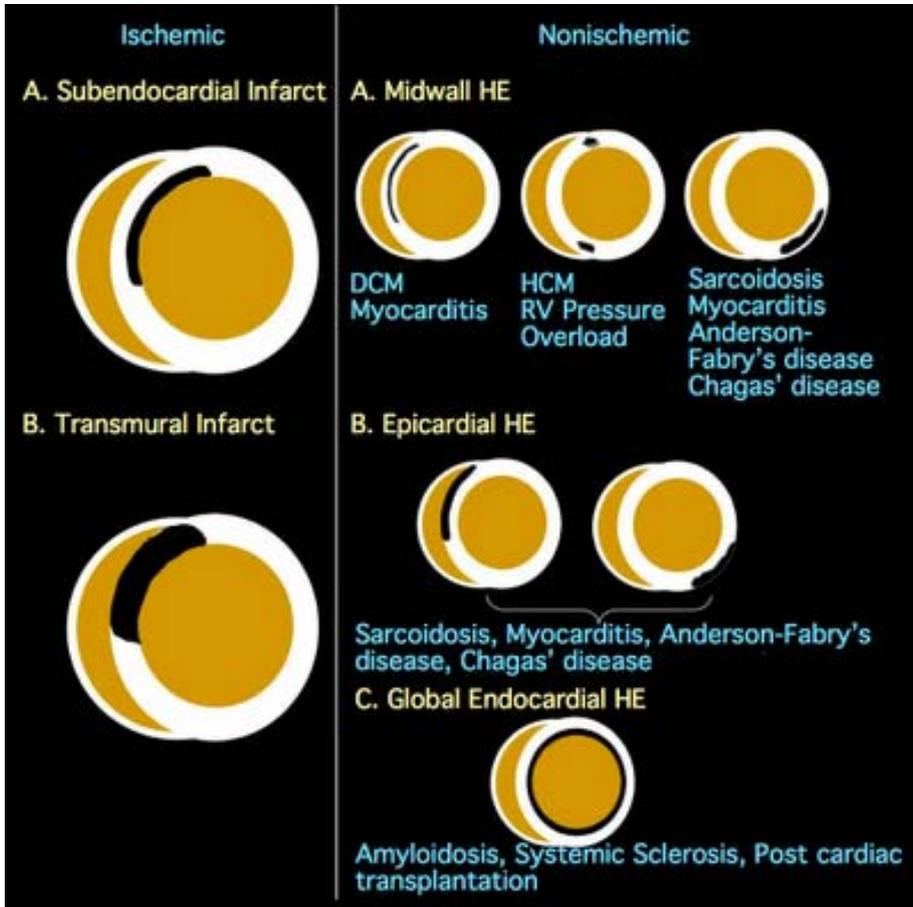
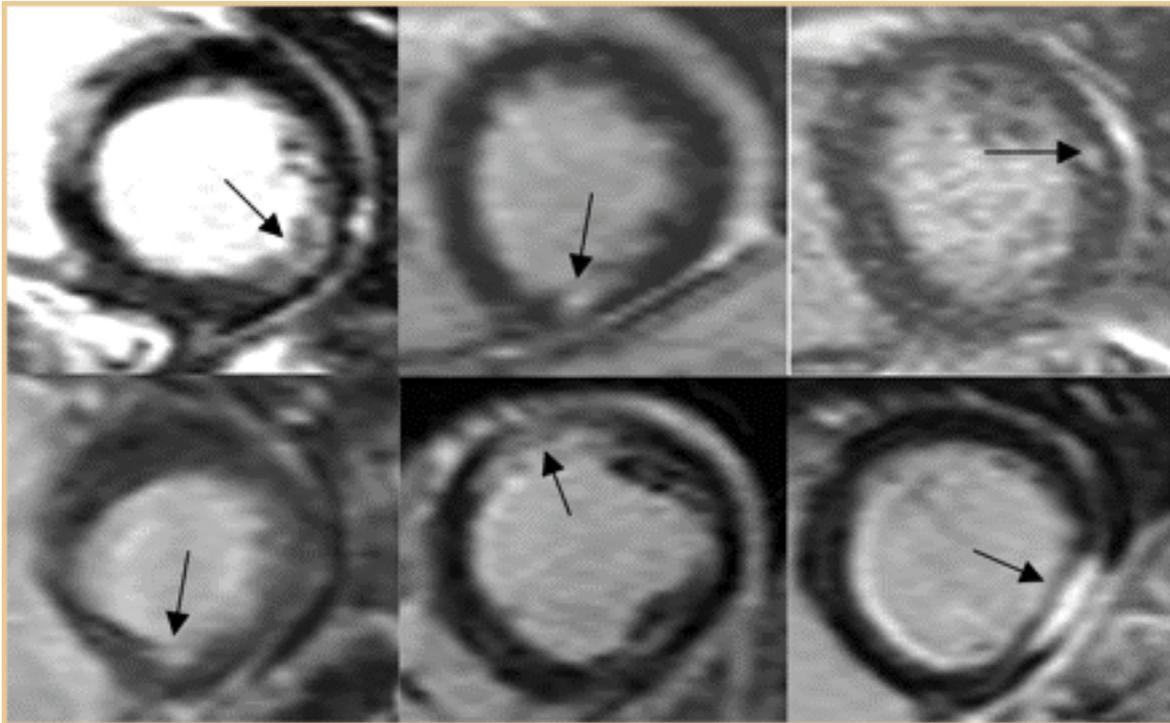
\*\*\*舉例\*\*\*



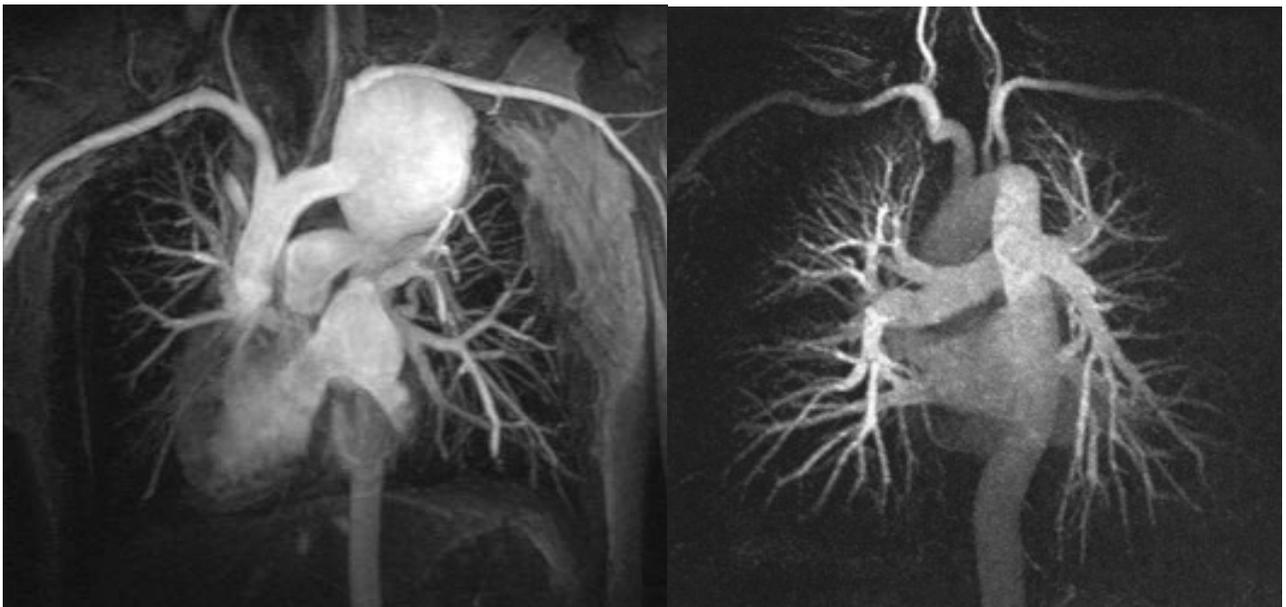
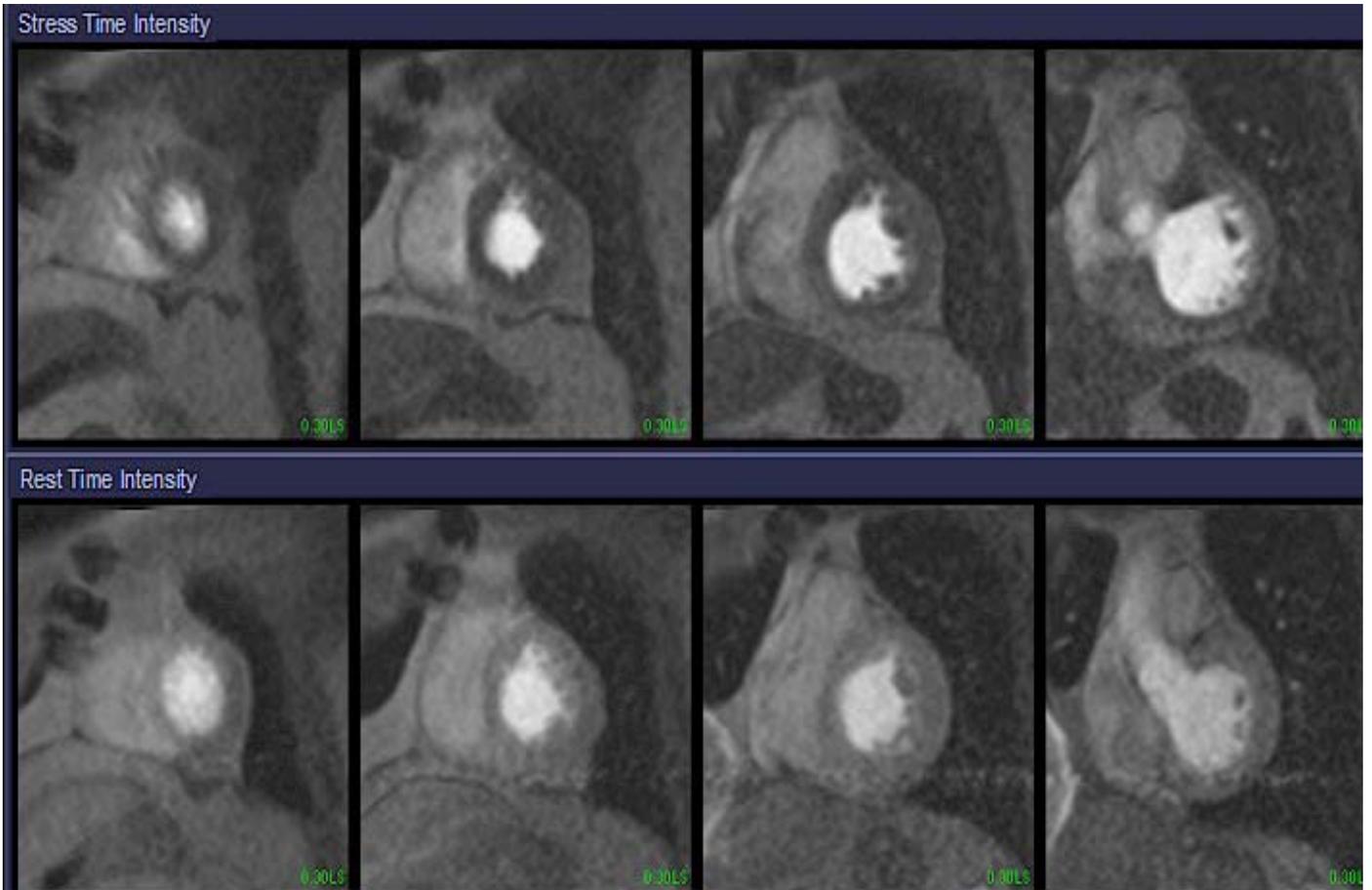


Patient Name:			
Patient ID:			Examination Date: 20020405
Patient Height: 63.43 in.	Patient Weight: 126.00 lbs.	R to R Interval: 772 ms.	
	LV Absolute	LV Normalized	
<b>Cardiac Function</b>			
Ejection Fraction	44.69 %		
<b>Cardiac Information</b>			
Myocardial Mass (avg)	118.29 ± 2.42 g	73.55 ± 1.50 *	
End Diastolic Volume	126.31 ml	78.54 *	
End Systolic Volume	69.86 ml	43.44 *	
<b>Additional Cardiac Function Data</b>			
Stroke Volume	56.45 ml	35.10 *	
Cardiac Output	4.39 L/min	2.73 *	
Peak Ejection Rate	---- ml/sec	---- EDV/sec	
Peak Filling Rate	---- ml/sec	---- EDV/sec	
<b>Temporal Data</b>			
Time to Peak Ejection Rate	---- msec	---- systole	
Time from ES to Peak Filling Rate	---- msec	---- diastole	
Heart Rate	77.72 Beats/min		
	* normalized to patient surface area	1.61 m <sup>2</sup>	

Delayed Enhanced imaging & Enhancement Pattern

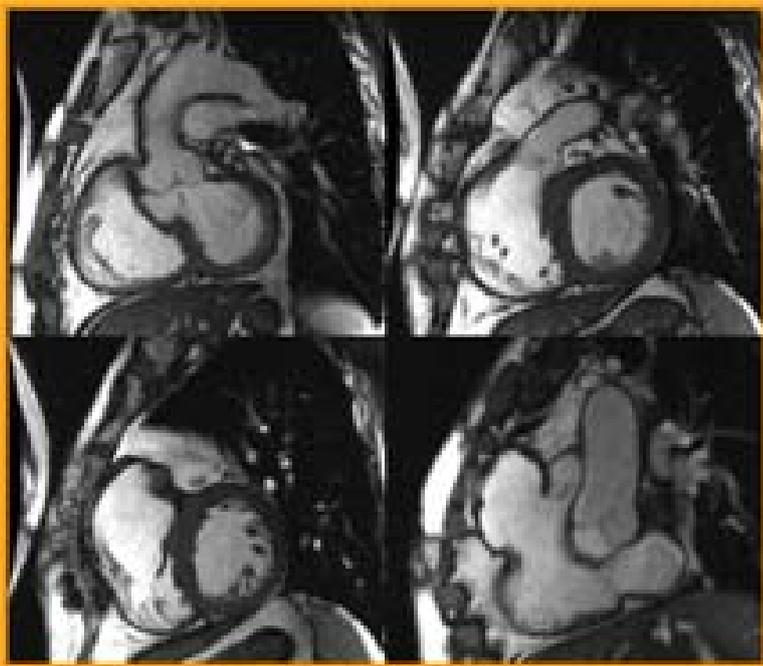


Stress perfusion scan with Adenosine

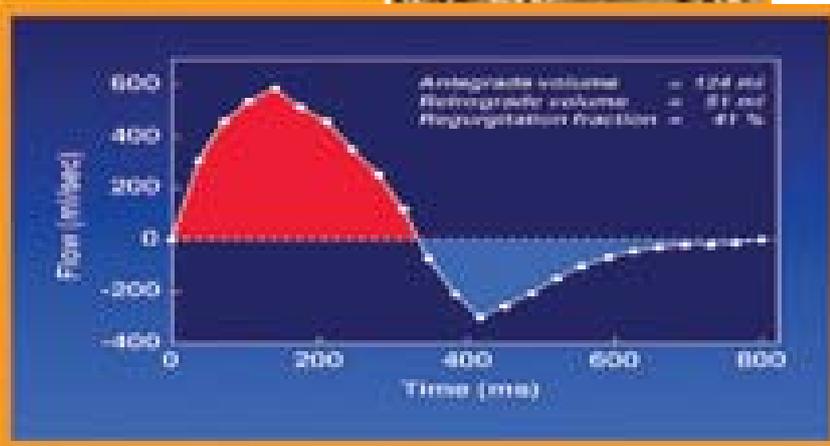


Contrast-enhanced MR Angriography

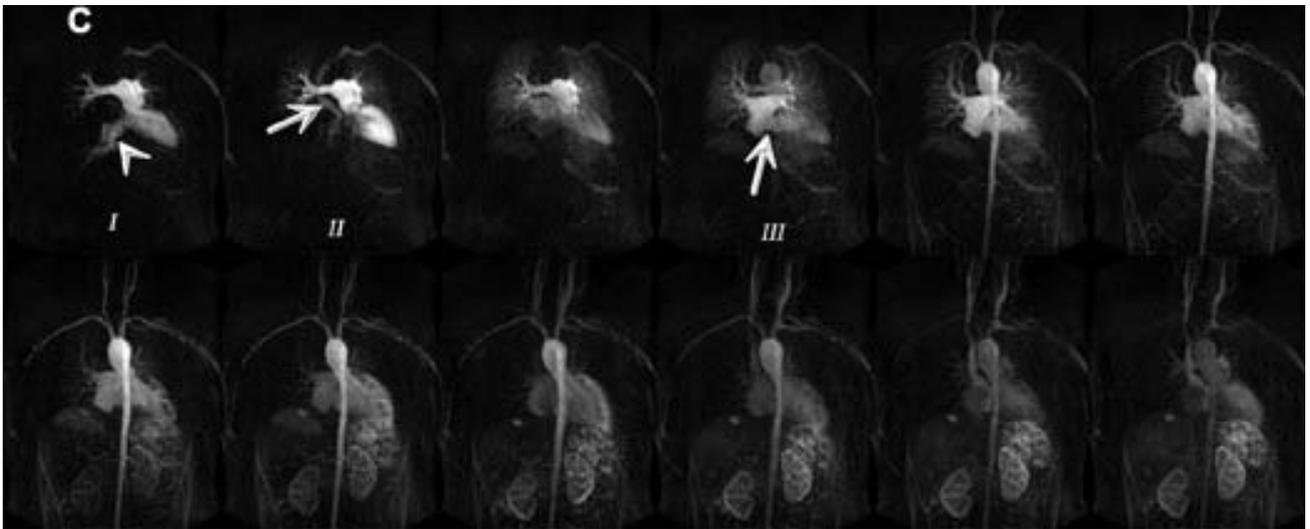
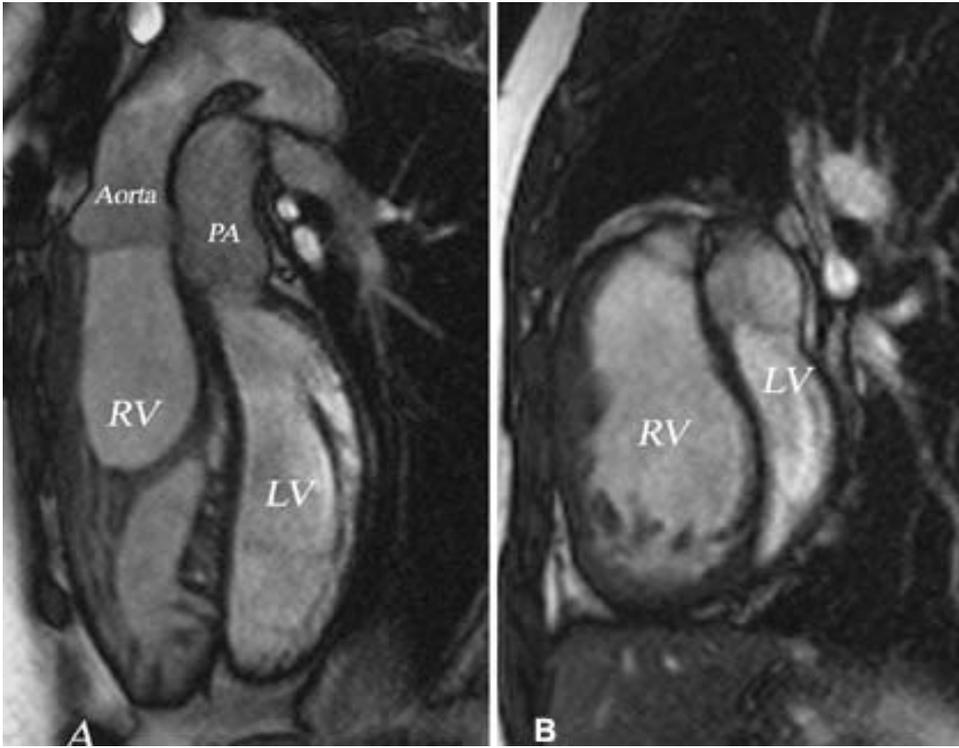
b. 成人型先天性心臟病  
i. 法洛氏四重症 (Tetralogy of Fallot)



- Postoperative patient with tetralogy of Fallot with VSD patient, **large RVOT aneurysm, RV dilation, and trace aortic regurgitation.**
- RVOT flow measurement:
  - Velocity mapping
  - Perpendicular plane
- Regurgitation fraction
  - Forward flow / reverse flow



ii. 大動脈轉位症( Transposition of Arteries)



#### 四. 參與國際會議之海報張貼作品

- a. 2009-10 NASCI Orlando (北美心臟影像醫學會年會，在佛州奧蘭多舉行)：  
*Evaluation of Late Complications of Post-Repaired Tetralogy of Fallot: Before & After Pulmonary Valve Replacement*



## Imaging Evaluation of Late Complications of post-repaired Tetralogy of Fallot: Before and After Pulmonary Valve Replacement

Tsun-Hou Chang<sup>1</sup> MD    Harold I. Litt<sup>2</sup> MD-PhD  
<sup>1</sup>Tri-Service General Hospital (Taipei, Taiwan), <sup>2</sup>University of Pennsylvania School of Medicine (Philadelphia, USA)

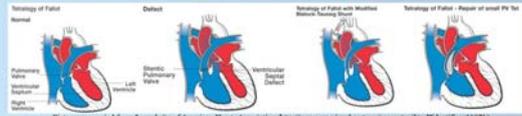


### PURPOSE ( LEARNING OBJECTS )

Understand the importance of imaging follow-up for adult Tetralogy of Fallot (TOF) patients.

- Recognize the imaging features of late complications of TOF.
- Identify the causes of late complications of surgical TOF cases and timing of pulmonary valve replacement (PVR).
- See the results of post pulmonary valve replacement.

### TETROLOGY OF FALLOT LATE COMPLICATIONS



Pictures are copied from the website of American Heart Association ([http://www.americanheart.org/printer\\_j.asp?identifier=11071](http://www.americanheart.org/printer_j.asp?identifier=11071))

Surgical management of TOF leaves anatomic and functional abnormalities in the majority of patients. Right ventricular volume overload from tricuspid regurgitation (Fig. e,f), pulmonary regurgitation (Fig. g), residual atrial and/or ventricular septal defect (Fig. c,d), conduit obstruction (Fig. i-j), right ventricular (RV) outflow tract patch aneurysm (Fig. a,b), and pulmonary artery stenosis (Fig. k,l) are some of the lesions frequently encountered in these patients.

### PULMONARY VALVE REPLACEMENT

**Indications and Timing of Pulmonary Valve Replacement (PVR)**

- Natural History:** Predictors including RV dysfunction, LV dysfunction, QRS duration  $\geq$  180 milliseconds, syncope, and sustained VT.
- Risks of PVR:** The operative mortality is low; as for valve failure and re-operation, to see the type of valve and patient age. Young age at PVR is higher risk of valve failure & early re-operation.
- Benefits of PVR:** Elimination or significant reduction of PR is associated with symptomatic improvement, decrease in RV volume.
- Criteria for PVR:** It must balance between the benefits of elimination of RV volume load before irreversible dysfunction occurs and disadvantages of valve failure and need for re-operation.
  - Severe PR ( $\geq$  25%) and two or more of the following criteria:
    - RV end-diastolic volume index  $\geq$  160 mL/m<sup>2</sup>;
    - RV end-systolic volume index  $\geq$  70 mL/m<sup>2</sup>;
    - LV end-diastolic volume index  $\geq$  95 mL/m<sup>2</sup>;
    - RV ejection fraction  $\leq$  45%;
    - RVOT aneurysm;
    - Clinical criteria: exercise intolerance, heart failure, syncope, sustained VT.
- Hemodynamically significant lesions such as moderate-severe TR, residual ASD or VSD, and severe AR may trigger referral for surgery in patients with moderate-severe PR.
- Due to higher risk of adverse clinical outcomes in patients.

### CONTENT ORGANIZATION

**Introduction:** Patients with TOF who had full corrective surgery during childhood are now surviving into adulthood. Many challenges remain arising from complications such as severe pulmonary regurgitation (PR), right ventricular (RV) dilatation, residual right ventricular outflow tract (RVOT) obstruction, VSD patch leakage...etc. It is important and imperative that adult TOF patients should have regular follow-up to monitor development and subsequent management of these complications. To evaluate these complications with imaging is comprehensive and effective to be investigational features for pulmonary valve replacement (PVR). We will show the imaging features of before and after pulmonary valve replacement.

**Objectives:**

- Describe the cases of late complications of surgical TOF cases.
- The conditions between pulmonary regurgitation and right ventricular dilatation are the cause & effect. PR is related to the use of transannular patch during RVOT reconstruction, and aggressive infundibulotomy involving the pulmonary valve annulus.
- Residual RVOT obstruction can persist after initial corrective surgery due to hypertrophied muscle in the subvalvular region, annular hypoplasia, pulmonary valve stenosis or branch pulmonary artery stenosis.
- The decision regarding the timing of PVR is based on a combination of both clinical as well as investigational features.
- Demonstrate the imaging features of late complications of TOF (before PVR):
  - severe pulmonary regurgitation (PR)
  - right ventricular (RV) dilatation
  - residual right ventricular outflow tract (RVOT) obstruction, VSD patch leakage
- Demonstrate the imaging features of after PVR of TOF cases.

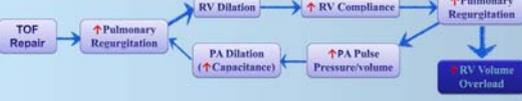
### TETROLOGY OF FALLOT MANAGERMENTS

Tetralogy of Fallot includes VSD, RVOT obstruction (pulmonary stenosis), overriding aorta, and RV hypertrophy.

**Surgical Treatment**  
 TOF is treated surgically. A temporary operation may be done at first if the baby is small. Complete repair comes later. Sometimes, the first operation is a complete intracardiac repair.

**Temporary Operation**  
 In small and very blue infants, shunt surgery may be done first to provide adequate blood flow to the lungs. This lets the baby grow big enough to have a full repair. The shunt is built between the aorta and the pulmonary artery. The shunt is removed when a complete repair is done later.

**Complete Repair**  
 Complete repair tends to be done early in life. Once it was more common to do a temporary operation first and a complete repair later in childhood, including VSD with a patch, opening of the RVOT by removing some thickened muscle below the pulmonary valve, repairing/removing the pulmonary valve & enlarging the peripheral pulmonary arteries that go to both lungs. Sometimes a stent (conduit) is placed between RV and PA. This is sometimes called a Rastelli repair.



### BIBLIOGRAPHY

- T. Geva, Indications and Timing of Pulmonary Valve Replacement After Tetralogy of Fallot Repair. Semin Thorac Cardiovasc Surg Pediatr Card Surg Ann 9 (2006), pp. 11-22.
- Hand-plotted pictures are copied from the website of American Heart Association ([http://www.americanheart.org/printer\\_j.asp?identifier=11071](http://www.americanheart.org/printer_j.asp?identifier=11071)).
- J.G. Murphy, B.J. Gerbasi and D.D. Main et al., Long-term outcome in patients undergoing surgical repair of tetralogy of Fallot. N Engl J Med 329 (1993), pp. 593-599.
- G. Nollert, T. Fischlein and S. Bouterwek et al., Long-term survival in patients with repair of tetralogy of Fallot. 36-year follow-up of 490 survivors of the first year after surgical repair. J Am Coll Cardiol 30 (1997), pp. 1374-1383.

### Before PVR Condition (Fig. m-q):

- Male-34 y/o., exercise intolerance, RV size: 397 ml (183 mL/m<sup>2</sup>, 106 x 55 mm)
- RV dysfunction: EIP% dropping (51%  $\rightarrow$  32%), SV dropping (209 ml  $\rightarrow$  126 ml)
- Pulmonary regurgitation (PR) increased (26%  $\rightarrow$  38%)

### After PVR Follow-up (Fig. r-v):

- Male-35 y/o., symptoms improved, RV size: 353 ml (162 mL/m<sup>2</sup>)
- RV improved: EIP% inverse dropping (32%  $\rightarrow$  47%), SV unchanged (126 ml  $\rightarrow$  128 ml)
- No PR after pulmonary valve replacement (38%  $\rightarrow$  0%)

b. 2010-01 SCMR Phoenix (心血管磁振造影醫學會年會，在亞歷桑那州鳳凰城舉行):

*Lack of Relationship Between RV volume, Degree of PR and LV function in Repaired Tetralogy of Fallot*




## Lack of Relationship Between RV Volume, Degree of PR and LV Function in Repaired Tetralogy of Fallot

Tsun-Hou Chang, MD.<sup>1</sup>; Harold I. Litt, MD-PhD.<sup>2</sup>  
<sup>1</sup>Tri-Service General Hospital (Taipei, Taiwan), <sup>2</sup>University of Pennsylvania School of Medicine (Philadelphia, USA)

---

### INTRODUCTION

- Tetralogy of Fallot (TOF)
  - Ventricular septal defect (VSD)
  - Right ventricular (RV) outflow tract obstruction (RVOT)
  - Overriding aortic ventricular septum
  - RV hypertrophy (RVH)
- Complete surgical repair in early childhood
  - VSD closure of the VSD
  - Relief of the RVOT obstruction
  - Patch, conduit
- Abnormalities after surgery
  - Residual or recurrent VSD,
  - Residual or recurrent RVOT obstruction
  - Pulmonic Regurgitation (PR) and RV dysfunction
- Role of cardiac MR in follow-up:
  - Anatomic evaluation
  - Parameter measurement, including right & left ventricular end-diastolic volume (EDV), right & left end-systolic volume (ESV), right & left ejection fraction (EF), and PR fraction (%)
  - Need for reoperative surgical reconstruction of the RV outflow tract (RVOT)
- Many previous studies focus on this related topics, and show conflicting results as following:
  - Positive
    - R. Andre-Niessen, et al. *Radiology* 1996;201:135-140
    - Pevkita A, et al. *J Am Coll Cardiol* 2002;40:3584-3592.
    - Eddie W.Y. Chong, et al. *Am J Cardiol* 2009;104:1264-1270.
  - Negative
    - R. Andre-Niessen, et al. *Heart* 1999;82:697-703.
    - Michael A. Gatzoulis, et al. *Am J Cardiol* 2005;96:1352-1357.

### PURPOSE

To evaluate the relationship between right ventricular volume, degree of pulmonic regurgitation (PR) and left ventricular function (LV EF%)

### METHODS

- 126 consecutive MRI examinations performed on adults with repaired TOF from 2005-2009 at a single center
  - 23 studies obtained after pulmonic valve replacement
  - 4 studies with only real-time cine (orthostatic or breath-hold images)
  - 99 exams on 81 patients for analysis
- Short axis SSFP cine
  - RV end-diastolic volume (indexed to body surface area)
  - LV EF
- Velocity-encoded phase contrast cine
  - Pulmonic regurgitant fraction
- Related records, such as past & personal histories, surgical notes and referral letters were reviewed from *retrospectively*

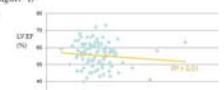
Parameter	Mean (SD)
Age (yrs)	35.5 ± 11.4 (14 - 64)
Male / Female	53 / 40
Time since repair (yrs)	20.6 ± 7.3 (16 - 45)
Blalock-Taussig shunt	25.3%
Waterston shunt	3.0%
Others	3.0%
Age at repair (yrs)	6.9 ± 6.8 (0 - 47)
RVOT patch	24.2%
Transannular patch	13.1%
Conduit repair	9.1%
RVOT aneurysm	11.1%
RVOT atresia	18.2%
PR fraction (%)	26.9 ± 17.3 (0 - 76)

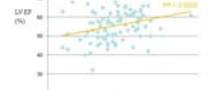
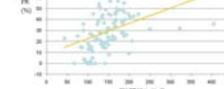
### RESULTS

- The 99 examinations (mean ± SD)

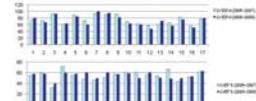
PR fraction (%)	RV EDV (ml/m <sup>2</sup> )	RV SV (ml)	RV EF (%)	LV EDV (ml/m <sup>2</sup> )	LV SV (ml)	LV EF (%)
26.9 ± 17.3 (0-76)	144.7 ± 52.2 (43-404)	104.7 ± 23.3 (45-209)	41.5 ± 9.1 (21-55)	74.6 ± 20.4 (29-147)	76.1 ± 22.9 (31-137)	55.5 ± 8.1 (32-72)

- No significant correlation between either RV EDV or PR and LV ejection fraction (EF), ( $r^2=0.01$  and  $0.0009$ , respectively) (Figures 1 and 2)
- Mild correlation between RV EF (%) and LV EF (%) (figure 3)
- Moderate correlation between RV EDV and degree of PR,  $r^2=0.18$  (figure 4)



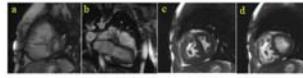



- See these LV function of 18 patients with two MR examinations, and no significant interval changes:



### DISCUSSION

- RV-to-LV interaction?
  - Previous study (Penkals et al) thought time to repair, aortic regurgitation (AR), and RV EPs are three predictors, but our study reveals insignificant
  - Previous study (Niessen et al) thought hypercontractility of the apex may constitute a form of remodeling of the left ventricle of TOF, which may lead to preservation of global function (stroke volume and ejection fraction)
  - Previous study (Eddie et al) thought paradoxical septal motion at the initial phase of systole associated with RV dilation attributes to restoration of the circular geometry of the left ventricle at the expense of effective fiber shortening



Here are examples of large RV (Fig. a-b) and D-shape LV with septal bowing (Fig. c-d), and their LV function & contractility show good.

### CONCLUSIONS

- No significant relationship between LV EF and RV size or degree of PR in a large, heterogeneous group of adults with repaired TOF
- LV function remains well preserved in many patients with very large RV volume and severe PR
- Diminished LV function can occur with any level of RV dilation or pulmonic regurgitation, and appears to be related to factors other than RV volume overload

## 肆、可發展重點:

### 甲、電腦斷層 (CT)

目前，本院有在執行的部份，僅限於多切面電腦斷層冠狀動脈攝影，故仍有很大的發展空間，舉凡心律不整電燒灼術之術前評估，主動脈瘤之術前評估及術後追蹤或先天性心臟病的術前評估及術後追蹤，都是很好的臨床發展，但仍須內/外相關科能協同一起發展。畢竟，診斷與治療是一個團隊。

負面來說，多切面心臟電腦斷層攝影所需的軟硬體設備（包含人力資源），所需投入之成本較一般電腦斷層檢查大很多，且也較複雜費時，在台灣的全民健保生態下，多切面心臟電腦斷層攝影所需付出的品質成本是健保給付無法涵蓋的，這是為何目前只能在自費健檢的領域發展。

### 乙、磁振造影 (MRI)

在台灣，已有數家醫學中心有在臨床上有漸進的發展；但在本院則似乎尚未起步，故發展勢在必為。在此草創時期，首先面臨的便是硬體的設定與人員的訓練目前的難處。尤其敝人在 Penn Medicine 所見之機型廠牌，與本院不相同，在磁振造影上，機器不同，所使用知名詞與設定、甚至功能則大不同，這是首要克服的。

其他後續，如後處理的執行，在軟硬體設施所遭遇的問題，則與多切面心臟電腦斷層攝影相同。

在美國，醫療支出是台灣的 30~40 倍以上的差距，這是為何常見到華僑特地回台灣就醫，正面來說，這是台灣奇蹟，台灣無須憂慮就醫問題；但負面來說，健保無力支付新的醫療發展，新的醫療發展的成本是昂貴的，如果健保發展只能在“量”上琢磨，而不能朝“質”的價值觀上演進。最終是劣幣驅逐良幣，台灣醫療不進則退。

### 丙、3D 醫學影像工作室

在 Penn Medicine，3D 醫學影像工作室扮演關鍵的影像品管的環節，所有影像的後處理，都是由特定的、訓練有素的放射師完成，則放射線專科醫師在判斷新的診斷，評估術前、術後的差異時，能更迅速準確。所以，這也是值得學習之處。



Guo-Shu Huang  
Chairman, Department of Radiology  
Tri-Service General Hospital  
No. 325, Section 2, Cheng-Kung Road  
Taipei 114, Taiwan ROC

26 March 2010

Dear Dr. Huang,

This letter concerns the research fellowship undertaken by Dr. Tsun-Hou Chang in the Cardiovascular Imaging section of the Department of Radiology at the University of Pennsylvania School of Medicine from March 2009 through February 2010.

During that time, Dr. Chang participated in many research projects including investigations of Tetralogy of Fallot, a study correlating left atrial appendage filling defects seen at cardiac CT with echocardiography findings, and the use of dual energy CT for quantitative measurement of bone mineral density without need for an external phantom. This research was presented at meetings of the North American Society for Cardiovascular Imaging, Society for Cardiovascular Magnetic Resonance, European Congress of Radiology, and Radiological Society of North America. Dr. Chang worked diligently on all of his projects, and showed considerable initiative in developing hypotheses, gathering and analyzing data.

Dr. Chang's study "Lack of relationship between right ventricular volume, degree of pulmonic regurgitation and left ventricular function in repaired Tetralogy of Fallot", presented at SCMR, was very well received and was the subject of considerable discussion. The study is the largest yet undertaken of this important topic, and will soon be submitted for publication.

Please feel free to contact me should you require further information.

Respectfully,

Harold Litt MD-PhD