出國報告(出國類別：進修)

結構性心臟病的心律不整治療

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摘要

筆者於美國亞利桑那州 Banner University Medical Center Cardiac Institute 電生理學科進行為期一年三個月的參訪與研究交流。此行的主要目的是學習結構性心臟病的心律不整治療，了解先進國家治療心律不整的最新發展。透過參與臨床病例討論，臨床研究設計，及手術觀摩，並觀察兩地醫療制度之差異，希望能借鏡這段時間的學習經驗，發展適合成大醫院電生理學科對於複雜性心律不整患者之健康照護模式。

目次

一、目的

(一)目標

本計畫有以下幾項目標:

1. 觀摩結構性心臟病之心律不整的電燒治療模式。
2. 加強成大醫院與美國醫療學術機構之臨床與學術研究交流。

(二)主題

本計畫包活以下幾項主題:

1. 電生理手術研究室臨床手術觀摩。
2. 心律不整研究交流。

(三)緣起

成大醫院約於 10 年前，由林立人副院長建立起心臟電生理研究暨手術室。當時雖然建置了 3D 立體電燒系統，但剛開始的手術與學術研究主要集中在 2D Fluoroscopy 導引，因此對患者的幫助僅限於較單純的心室上心律不整，如陣發性心室上心搏過速等。然而，結構性心臟病所引起的複雜心律不整，唯有 3D 立體電燒系統的輔助才能精準定位。在約 5 年前，成大心臟內科黃鼎鈞及李柏增醫師前往台北榮總取經，將聞名的”台北經驗”學成後帶回，大幅的推進了成大心律不整治療的進展，尤以心房顫動的治療最為耀眼。而後數年間，更有幸邀請國際心房顫動冷凍治療的知名大師 Dr. Wilber Su 至成大示範手術教學，建立成大與美國 Banner University Medical Center 的學術交流。Dr. Wilber Su 是

Banner University Medical Center 心臟電生理的主任，其創建電生理團隊的過程中引入 Dr.Roderick Tung, Dr.Peter Weiss 及 Dr.Michael Zawaneh，使得整個團隊能完整地覆蓋電生理治療的各個領域，包括心室心律不整、Robotic surgery 及各種節律器置放。藉由黃鼎鈞醫師的引介，本人有幸能藉由電子郵件取得與 Dr. Wilber Su 的交流，並促成此次為期一年多至 Banner University Medical Center 學術與臨床的參訪。

(四)預期效益

本計畫預期達成以下效益：

1. 增進個人對複雜性心律不整相關知識與技能
2. 建置適合成大電生理實驗室對於複雜性心律不整的醫療照護模式
3. 加強台灣與美國雙方醫療照護的學術交流

二、過程

(一)起頭

九月是台灣即將入秋的季節，遠在太平洋另一側的亞利桑那州卻還是豔陽灼灼。有幸獲得醫院的經費資助，這次將造訪的城市是亞利桑那州的行政中心鳳凰城，也是美國人口第五大城市。這座坐落在沙漠中的西部城市有著近 42 度的高溫，高大的仙人掌在升騰的乾熱空氣中微微搖曳。Banner University Medical Center 是當地最大的醫療系統，其分院廣布整個亞利桑那州。而本次參訪的是靠近市中心的 cardiac institute，是一所專門診治各種心臟疾病的分院，尤以心臟移植聞名。

(二) University of Arizona

亞利桑那大學是亞利桑那州第一個設立的大學機構，與亞利桑那州立大學(Arizona State of University)並列為區域內最好的學術機構，也是唯一設有醫學系學制的大學。其學區共有 10 幾個，分布於整個亞利桑那州，校園腹地廣大，景色優美，於不同學區亦能欣賞到亞利桑那州各種獨特的地理風貌。在早期設立醫學系時並沒有同時設立實習醫院，近年來在多方的努力協調下與亞利桑那州最大的醫療系統(Banner)達成建教合作並完成合併，使得人才培養、醫療服務以及學術研究能相輔相成。

(三)Banner University Medical Center

3.1 Cardiac institute

心血管中心坐落於鳳凰城市中心，是一座結合現代醫療與歷史建築的當地地標。其編制完整，分工獨立，包括心血管外科、心臟電生理科、心衰竭科、心臟超音波科、結構性心臟病科及心臟移植小組等均有專門的醫師團隊負責。除此之外，放射部門及 EMT 救援系統完整，能與心臟相關部分緊密且有效率的配合。

圖一、Banner University Medical Center

3.2 Department of electrophysiology

由 Dr.Wilber Su 所領導的電生理團隊有完整的人員、門診、住院病房及導管室編制。醫師部分共有 4 位專責醫師，其中 Dr.Wilber Su 及 Dr. Zawaneh 專精於心房心律不整及各式節律器置放，Dr. Tung 及 Dr.Weiss 則專責心室心律不整。病房及

門診有 2 位訓練中的 fellow 及 4-5 位 nurse practitioner 負責，並設有 3 間專責心律不整手術的 EP lab。每週一上午整個團隊針對所有住院會診之病人以及當周手術進行討論及交班。每週三、週五上午由 fellow 報告上週的特殊 case，並由主治醫師給予指導教學。手術室的技術人員由具經驗的組長負責調派，每一台手術除主治醫師外，均配有 1 位刷手技術人員，1 位護理師，1 位電訊號技術人員，1-2 位廠商工程師，1 位麻醉醫師及麻醉護士。值得一提的是麻醉醫師與主刀醫師的分工明確，術中的血液動力學管理均由麻醉醫師負責，使得電生理的主刀醫師能專注於完成手術。研究部門專門的 research coordinator 負責，其串聯醫師、研究 fellow、廠商、合作醫院以及國家研究機構，定期舉行研究會議，確保各研究能符合倫理規範並合乎研究進度。

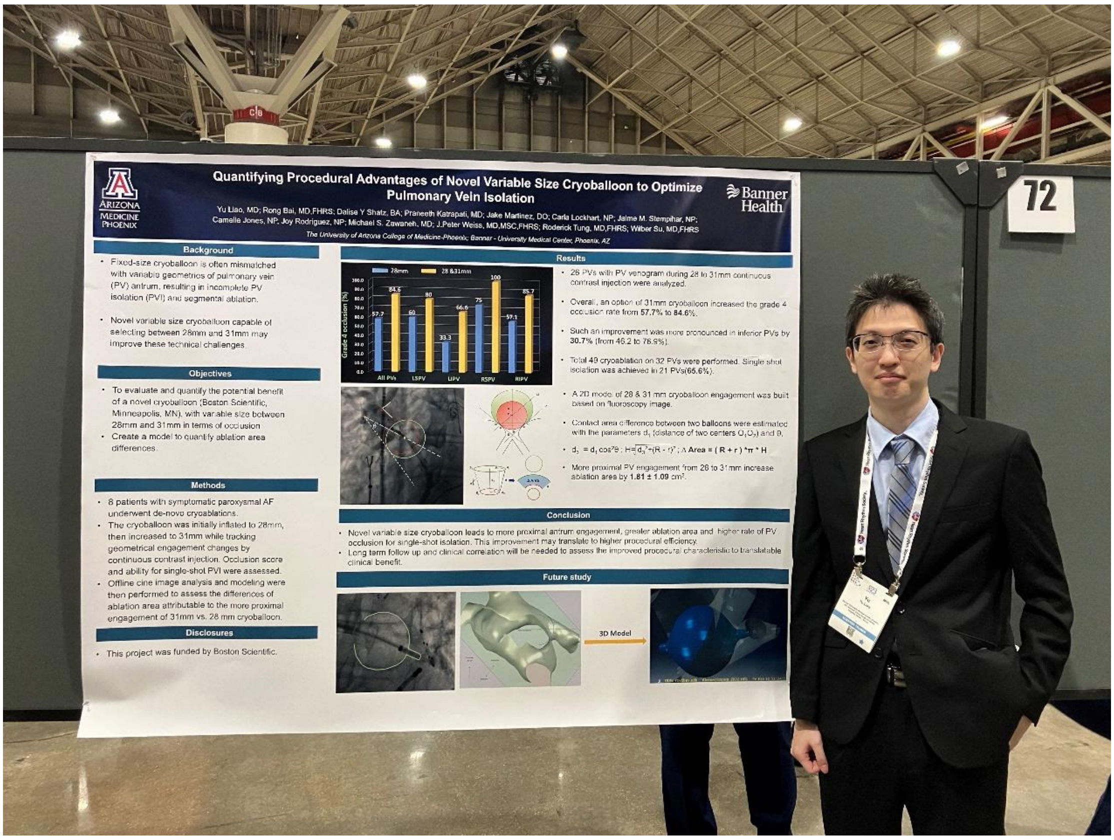
圖二、Electrophysiology Lab team members. 左一 Dr. Rong Bai, 左二 Dr. Wilber Su, 左四 Boston Scientific engineer Celeste, 左五 Research Coordinator Yi Dalise, 左六&七 EP lab and Anesthesia nurses.

(四)參與國際學術會議

4.1 2022.11 於 Arizona 參加 ACC/AHA 區域會議。Poster 題目為 QTc calculation By Different Formulas under Different Heart Rhythm，探討在 atrial fibrillation 及 Sinus rhythm 下使用不同校正公式(包括 Bazetts, Fridericia, Framingham,Hodges, Dimitriensko 等)評估患者的 QT 時間。結果顯示 Atrial fibrillation 不會對患者的 QTc 產生顯著影響，且 Bazett formula 最容易 overestimate QT interval.

圖三、Arizona local ACC/AHA meeting 留影。

4.2 2023.5 於 New Orleans 參加 Heart Rhythm Society Annual Meeting。 Poster 題目為 Quantifying Procedural Advantages of Novel Variable Size Cryoballoon to Optimize Pulmonary Vein Isolation. 探討 Dual sized Boston Scientific Cryoballoon 在執行 Pulmonary Vein isolation 時能提供的額外優勢。結果顯示 dual sized cryoballoon 能顯著提高 grade 4 PV occlusion rate(57.6 to 84.5%)，並於 2 dimensional 數學模型中，推估 31mm balloon 能增加 PV antral ablation 的面積 $1.81 \pm 1.09\ cm^2$.



圖四、Heart Rhythm Society Annual Meeting 留影。

(五)學術論文發表

於出國進修期間，共發表 3 篇學術論文，包括一篇 review 及兩篇 original article，簡述如下。

5.1 Liao Y, Katrapati P, Bai R. Risk and benefit of extrapulmonary vein ablation in atrial fibrillation. Curr Opin Cardiol. 2023 Jan 1;38(1):1-5. doi: 10.1097 /HCO.0000000000001002

此篇 review 統整近期針對心房顫動電燒於 Pulmonary vein isolation 以外的電燒技術進展，包括 posterior wall isolation, linear ablation, ablation for extrapulmonary triggers 及 substrate based ablation。並針對各項 strategy 闡述其成效、安全性，以及對未來手術發展提出見解。

5.2 Liao Y, Tomaiko-Clark ED, Martinez J, Shinoda Y, Morris MF, Liu Z, Shatz DY, Katrapati P, Sahara N, Weiss JP, Zawaneh MS, Tung R, Bai R, Su W. Incidence of cryoballoon expansion dislodgement during pulmonary vein isolation-an underappreciated frequent cause of incomplete isolation. Pacing Clin Electrophysiol. 2023 Dec 23. doi: 10.1111/pace.14910. Epub ahead of print. PMID: 38140909.

此篇原著論文探討心房顫動氣球冷凍電燒過程中，因氣球冷卻降溫後物理性質改變而引起的氣球移位。氣球的移位以 dielectric imaging-based occlusion tool (DIOT)及 intracardiac ultrasound 等特殊影像系統偵測。

4 WILEY LIAO ET AL.

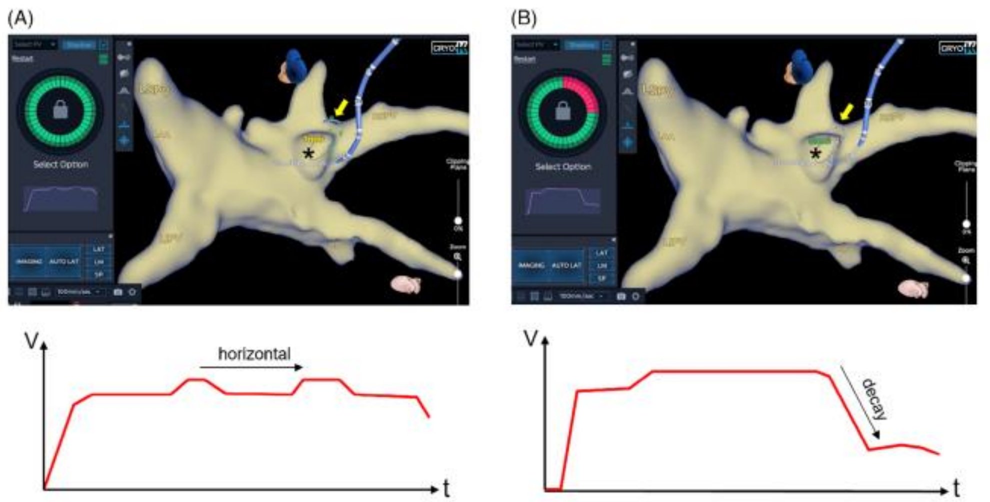


FIGURE 1 Expansion dislodgement of cryoballoon detected by dielectric imaging-based occlusion tool (DIOT) at right superior pulmonary vein (RSPV). (A) Prior to freezing, a complete green circle indicated total PV occlusion (top), corresponding to no amplitude decay in the real-time dissipation waveform(bottom). (B) Immediately after freezing, upper right electrodes signals changed to red (top) and an amplitude decay was found in the real-time waveform (bottom), indicating a balloon dislodgement with posteroseptal leak. This application ended up with failed PVI. Asterisks: position of cryoballoon. Arrow: achieve mapping catheter. [Color figure can be viewed at wileyonlinelibrary.com]

圖五、Dielectric imaging-based occlusion tool(DIOT)method to detect expansion dislodgement of cryoballoon.

5.3 Liao Y, Bai R, Shatz DY, Weiss JP, Zawaneh M, Tung R, Su W. Initial clinical experience of atrial fibrillation ablation guided by a cryoballoon-compatible, magnetic-based circular catheter. J Cardiovasc Electrophysiol. 2024 Jan;35(1):111-119. doi: 10.1111/jce.16124.

此篇原著論文分享新型磁場相容性診斷導管於心房顫動冷凍電燒手術的使用經驗，並與過去常規使用的高密度導管成效於多方面進行比較，包括心臟解剖結構相似度、遠離訊號電位(far field electrogram amplitude)及心律不整基質(arrhythmia substrates)等。

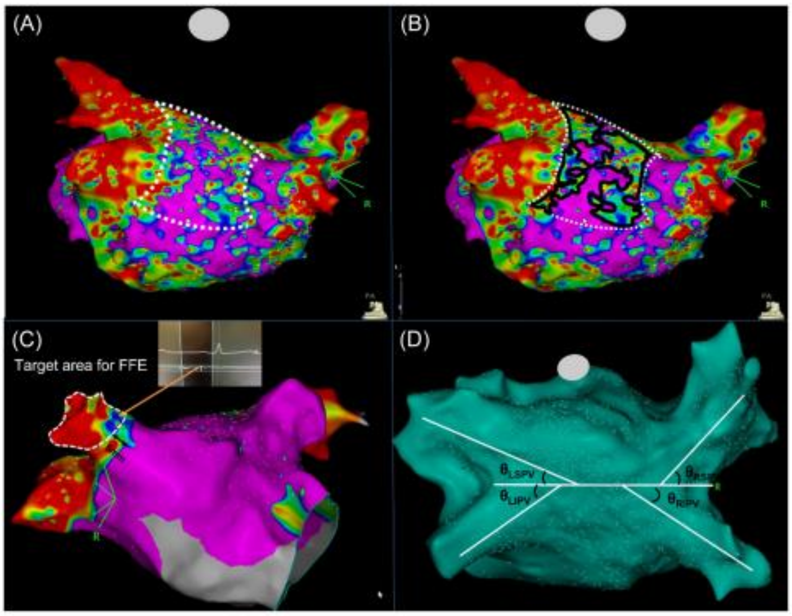


FIGURE 2 Definition of different measurements on EAM used in the study. (A) The LA posterior wall area was defined as area encircled by left atrium roof line, bottom line, and pulmonary vein-left atrium junction (area circled by white dot line). (B) Low voltage area was defined as bipolar voltage 0.1–0.5 mV within posterior wall area (area circled by black line). (C) Far field electrograms were sampled 5 mm distal to the ablation boundary. (D) Measurement of four pulmonary veins angulation. EAM, electro-anatomical mapping; LA, left atrium.

圖六、Comparison between LASSONAV and Pentaray catheter.

三、心得

很榮幸獲得短期出國進修的機會，尤其在完成專科醫師訓練之後，能夠前往技術更先進的研究中心持續進修，將新獲得的收穫應用於將來對患者的服務與照顧。除了臨床技術外，這次更涉獵了研究，希望能融會貫通，於成大設計出能符合本院 IRB 與健保規範的研究。以下提供粗淺的心得以供分享。

(一)打破框架，面對困難

在台灣生活長大，在醫院工作也已達 10 年，對於生存所需早已如魚得水。但一旦來到陌生的新環境，各種困難接踵而來，語言、文化的隔閡甚至是種族歧視是我在美國遇到的一大挑戰，此時更需要調整自己的心態耐心地勇於面對。不論是租房、開立美國帳戶、購買代步車、跨洲通勤、申請報稅與社會安全碼等等，每個步驟都常遇到意料之外的困難，幸而能遇到友善的指導，給予生活上適時的幫助。也遇到有相同背景、興趣相投的他國進修生，大家互相交流扶持，讓我獲得幾位患難與共的新朋友。希望能將這些社會經驗整理出來，分享給將來有意前往美國進修的後人，使得他們的進修之旅可以更加順遂。

(二)虛心學習，融入當地醫療文化

雖然在台灣已通過專科醫師的訓練並值業數年，自認已具備獨立診治病人的能力。然而美國的醫療常規有別於台灣，更強調專業的分工。舉例而言，一位心臟科的患者住院，是由一般心臟科醫師照顧。當他有其他方便的問題時，例如心衰竭、心律不整或冠心症，才會照會個心臟次專科介入照護。因此一位心臟

科的患者可能同時有數個團隊共同照護。剛開始覺得這樣的模式有些難適應，因為患者的醫囑常會有多個團隊同時下達，有時難免會有衝突之時。但後續發現只要經過良好的團隊間溝通，各團隊之間可以發掘彼此在照顧患者的盲點並給予建議，使得患者受到完善的治療。除此之外，由於獨特的醫療保險制度，美國的患者無法像在台灣一樣隨意地前往醫學中心就醫，往往需要層層的轉介。一位在醫學中心接受完處置的患者，也會回到地方醫療系統進行追蹤。因此醫療資訊的共享，以及各醫療機構之間的溝通，顯得格外重要。

(三)電生理知識學習心得

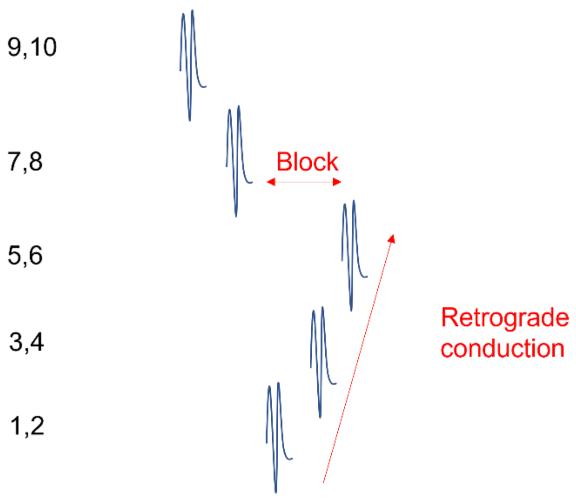
在每周的晨會、病房巡迴教學以及會議參訪中，不定時會學習到新的電生理知識。這些知識雖然看似零碎，但補足了原本的缺漏。茲將當時的隨筆整理如下。

0.General

0.1 The average of impedance of blood is around 90. And it's around 105-120 in average in LA tissue. A 15-impedance drop is desired to see for each ablation. (Boston rhythmia system)

0.2 When you ablate in CS with irrigation catheter, use 20w to start up.

0.3 When intrafascicular block occurs, there is a split H or fascicular potential. And it probably looks like Retrograde conduction.



0.4. The ERP is the shortest interval that does capture, so you have to add 10ms on the interval that blocks.

0.5 Non decremental refractory: atrium, ventricle, most AV bypass tracts, HPS. Decremental refractory: AV node, some AV bypass tracts(eg: PJRT)

0.6 During atrial extrastimuli, if APERP and AVERP occurs simultaneously, Try prolong S1, then prolongs APERP and get APERP when delta wave disappear.

Try shorten S, then prolongs AVERP and get full preexcited.

0.7 During ventricular pacing to see the position of accessory pathway. Initially the result will be the combination of retrograde HPS and AP conduction(earliest A may change?) You need to pace until HPS refractioness to see the position of AP.

0.8. If you wanna see more antegrade AP conduction, pace closer to the AP (far away from HPS). eg: pacing at distal CS for LL paceway.

0.9 The number of pacing to overdrive the tachycardia via RV pacing could be used to differentiate AVNRT and orthodromic AVRT. Typically AVRT takes fewer number, but LL pathway could be an exception.

0.10. His refractory VPC advance both A and tachycardia proves the existence of AP and its involvement in TCL. Usually, you need to advance A first before you advance the TCL. But nodofascicular is the exception.

0.11 .Put a linear catheter along left septum to acquire left side his-LPF, purkinje potential. To differentiate His from LPF, find the corresponding right side His.

0.12. Do a LBB EP study before PPM insertion for baseline LBBB pattern ECG.

If an intra-his block is seen, the success rate for LBB pacing is high.

If an intra-LBB block is seen, the success rate for LBB pacing goes down.

If you see the purkinje potential, LBBB is not working. The patient might have intraventricular block and a CRT should be considered.

1.SVT

1.1 Typical flutter: Sometimes it's better to ablate at 7'o clock, since the endocardium is flatter and thinner.

1.2 Typical flutter: when you are doing the differential pacing to check the bidirectional block, its recommended to pace at the rate slightly faster than the sinus rate, since functional block could occur at higher rate. However, the CTI is not truly block at lower rate.

1.3 SVT with wide QRS and, V more than A: AVNRT; JT with BBB.

1.4 1.4 Check phrenic nerve with pacing at 20mA before ablation at RA posterior wall

1.5 Pacing higher rate above SVT is an overdrive pacing. Some criteria needs to meet for entrainment.

1.6 D.D for incessant SVT: AT, JT, PJRT.

1.7 Early APC terminate AVNRT though block in pathway, but has no effect on JT. Late APC(His refractory) APC advance, delay or terminate AVNRT through slow pathway.

1.8 It's always good to localize the AP during AVRT, because during V pacing, the retrograde A is the combined result of AP and HPS conduction. On the other hand, ablation during AVRT is not a good idea, because the catheter pop out when the tachycardia terminates.

2. VPC

2.1 Summit

Catheter preparation:

20 pole, 3mm catheter in the coronary sinus, extend it in to AIV.

Ablation: 40-50watts

2.2 Cusp VPC:

Only V signal -> RCC, Only A signal-> NCC, both signals: LCC.

2.3 Posterior papillary muscle VPC: RBBB posterior axis.

2.4 AMC VPC: qR in lead V1

2.5 When looking for the site of best pace mapping, keep pacing and move catheter in RVOT.

2.6 VPC origin correlates to ECG leads and fluoroscopic views.

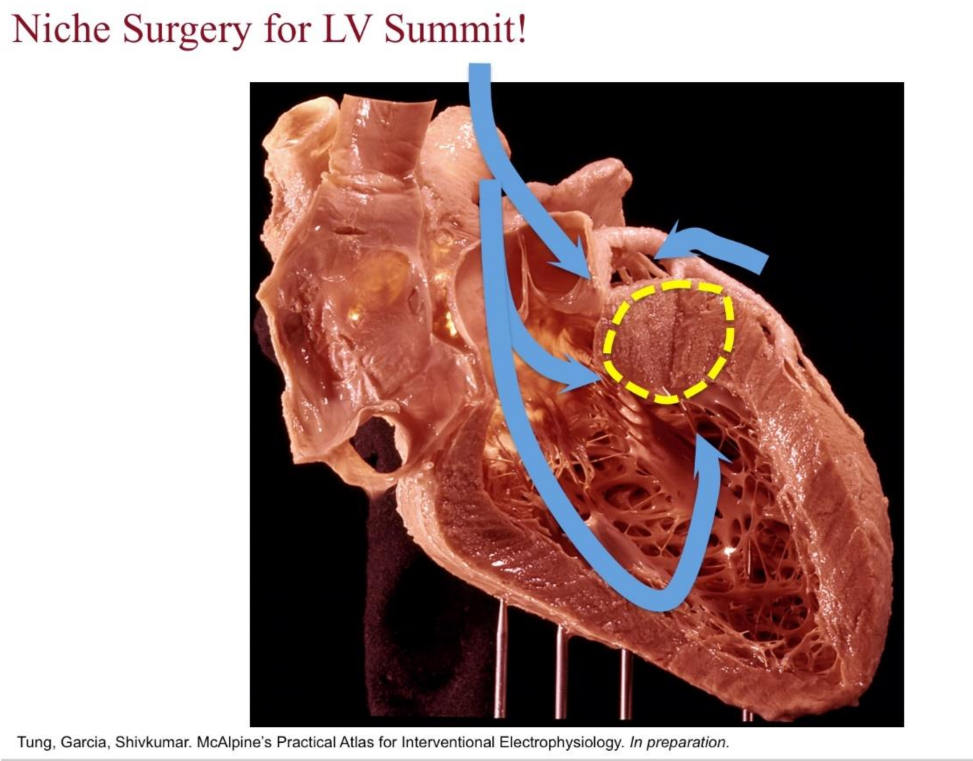
RBBB: LV origin; LBBB: RV or LV septum

RAO: best view to see superior or inferior axis, compatible with inferior ECG leads

LAO: best view to see lateral or medial axis, compatible with lead I, aVL

Positive concordance: basal LV; Negative concordance: apical LV. No obvious concordance(with R wave transition: mid LV)

When lead I is completely qs, suggests epicardial origin, since no myocardium is left to the epicardium.
If lead II and III are all positive, compare the R voltage of them, if II > III, it’s septum origin, if III>II, it’s lateral origin. Could compare aVR and aVL in the same way.
2.7 Methods to ablate summit VPC: via LCC, IFT, anterior AMC or AIV(Check coronary angiogram first, since its route overlap with OM or intermediate branch).
2.8 when a LBBB morphology like VPC is hard to ablate, try ILT XD.



LV summit VPC may have similar activation timing at several places, eg. AIV, LCC, RVOT. Compared the timing of endo(LCC) and Epi (AIV), if the timing is similar, it means it’s probably intramural VPC. May try higher watts or half saline.

3. VT
3.0 Ref: max -dv/dt. Window: from QRS onset to whole CL.
3.1 Those area with fractionated EGMs and borderline voltage are the pearl. Those area with definite dead tissue and healthy tissue are not the target. To check the viability of tissue, pacing at 10-20mA could be performed.
3.2 If there are many isochrone crowding areas, pace around those areas and match the morphology with VT. Also look for long pace-QRS and selected capture of the late potentials.
3.3 The closer you are, the more splits you will see at the lines of block. That’s why

CTI block is always *concealed* during sinus rhythm. In addition, concealed block often presents as normal EGM, unless you pace near them, then uncover the split signals.

3.4 Pace mapping:

if you pace at two sites next to each other, and you get two different VT morphology with two opposite axis, you are in the circuit with two exit sites.

3.5

The meaning of **"lines of block"** could be different in LV compared to in LA. Because LV has a thicker 3D structure. The wavefront that blocks at lines of block will continue to dive into intramural layer and then come out later from the other side of line. It means the isthmus may sit inside intramural layer, and the **" lines of block"** is the boundary of conduction block at endocardial surface.

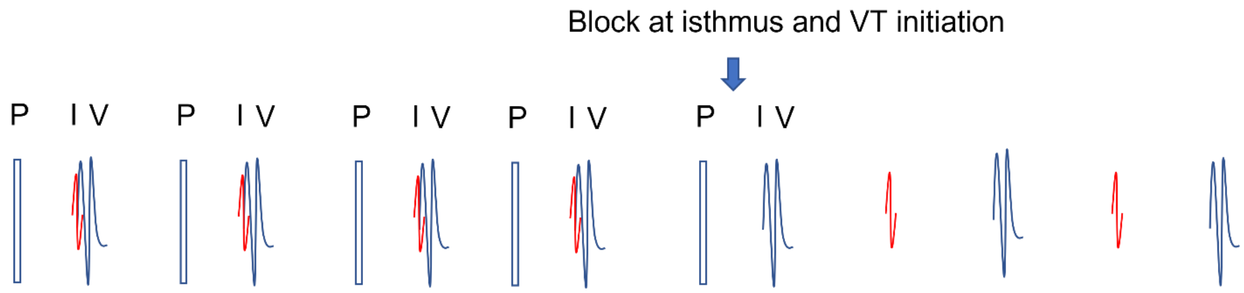
3.6 VT has several categorical methods, including conduction system VT or myocardial VT. V5-V6 leads are the best leads to tell them apart. If there is slurred initial parts, it's myocardial VT. If it's straight, it's conduction system.

3.7 For diagnosis of conduction system VT, a His signal is the most important. You always wanna find His-His preceding and predicting V-V interval. In addition, entrainment by atrial pacing is achievable.

3.8 Dr.Tung's theory: one can induce VT more easily if his pacing is closer to the circuit.

3.9 Crux VT: Often seem in NICM. ECG: equivocal V1, superior left axis(QS in lead II or III?), abrupt V2R. Anatomy: intersection of PDA, RCA, MCV.

3.10 Initiation of VT EGM at isthmus. The sequence of isthmus and V signal will change.



3.11 Progressive TR fusion will be seen if you pace from lower rate toward VT CL. Therefore, the best way to observe the pace mapping match is to pace at VT CL.

3.12 Four clinical interventions to improve VT ablation outcomes: 3D mapping, epicardial ablation, homogenization, mechanical circulatory support.

3.13

EGM annotation of ILAM map during sinus rhythm: annotate the latest EGM. If there is double potential, annotate the later one. A line of block will be always seen at the place with double potential.
EGM annotation of ILAM map during VT: annotate the sharpest EGM. The window of ILAM is set between two QRS onset. So the purple to white is the exit site (which is usually broad). The timing between S to Q is diastolic phase, and the color green-light blue is the mid diastolic phase.
3.13.1 The shape of isthmus is more important than the timing. The timing could be green, light blue or dark blue, but the color with cone-shape(narrow part) should be the isthmus.
3.14 The earliest ventricular parts of activation during sinus rhythm are the LAF-purkinje and LPF-purkinje junction, which locates at the middle part of posterior septum and anterior wall. Then the wavefront goes toward three directions.
1.Middle LV to His. 2.Middle LV to apical LV 3. Anterior and septal wall to lateral wall.

4. Afib

4.1. The benefit of mapping with CS pacing (eg. at 600CL) is quicker. Also stabilize

the rhythm during

四、建議事項

(一)引進醫療新品

這次筆者在美國的 EP lab 見識到很多成大沒有的醫療藥品及器材，除各先進國家引進的醫療新品外，更有醫療方與廠商共同設計的衛材進行臨床試驗，例如藥物(sotalol, dofetilide)、心臟內超音波(Intracardiac echocardiography)、新式的冷凍球囊(POLARX, BSCi 及 Synaptics), Pulsed Field Ablation(PFA)、Robotic ablation system 以及各式的多導極 mapping 導管。這些多元化的醫療器材使得術者能夠針對患者的需求有更彈性的選擇。筆者明白醫療新品的引進不易，需要合乎健保規範，也要通過招標、議價等過程以確保醫院的盈利。然新品的設計往往使術者能更有效率的執行手術並提升患者的安全，因此希望在新品的引進上能夠獲得院方多多的支持。

(二)建立獨立的 EP 導管室

Banner University Medical Center-Phoenix 共有 3 間獨立的 EP lab，全天專職進行心律不整電燒手術或各式節律器置放。然成大目前僅有 1 間導管室能夠進行完整的 3D 立體電位電燒，且此間導管室必須與其他 Vascular intervention 共用。在處理結構性心臟病的複雜性心律不整時，例如心室頻脈電燒，往往需要 4-6 小時的手術時間，倘若此時有緊急的心肌梗塞患者，心律不整的手術可能需要提前終止。因此若能效法 Banner University Medical Center 建置獨立的 EP lab，將使術者更能心無旁騖，挑戰更困難的術式。此外，也需訓練專責於 EP lab 的

技術人員。一台成功的電燒手術往往需要結合對心律訊號的判讀及術者操作導管的技術。在手術室外的技術人員若能具備基本判讀心律訊號的能力，便能導引術者進行有效率的電燒。成大導管室致力於訓練技術人員判讀心律訊號的能力，然目前僅有 3-4 位技術人員具備相關能力，倘若遇到例休或值班時間這些人員無法參與手術，術者則必須同時兼顧操作與判讀，分身乏術。因此，建立獨立的 EP 導管室並訓練專責的技術人員，將大大地助益成大心律不整治療的發展。

(三)經費補助與人員選派

台灣心律不整治療的領頭羊為台北榮總醫院，成大醫院亦曾派兩位主治醫師前往北榮進修。然據筆者之觀察，台灣在心律不整治療這個層面仍弱後頂尖國家 10 年以上。因此，為逐步趕上國外的成績，持續選派人員出國進修不能旁廢。出國進修參訪的開銷非常吃重，除日常生活開銷外，於國外參與國際會議之交通住宿也應考慮酌情補助。除了補助個人單訪進修外，也應考慮促成整個研究團隊的參訪。以心律不整的健康照顧模式為例，可以考慮補助除心臟科醫師以外的技術人員及導管室護理師前往。除此之外，在人員回國之後繼續給予資源發展與評估，協助其專注於發展所學而非派往其他任務，更能強化其學習動機，並將所學真正落實於成大。