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Restoration of Transposed Great Arteries With or Without Subpulmonary Obstruction to Nature

Ing-Sh Chiu and Chi-Ren Hung
Department of Surgery, National Taiwan University Hospital and National Taiwan University, College of Medicine, Taipei, Taiwan

Surgical correction on transposition of the great arteries was proposed by many in the past half-century, and was claimed as the anatomical correction; but the treatment of choice was ever changing. The current technique usually included Lecompte maneuver to bring the pulmonary bifurcation in front of the aorta. Although the ventriculoarterial connection was corrected, it is not "normal" yet---------.

1. Introduction

Looking back into the evolution of surgical treatments on transposed great arteries (TGA), is full of fascinating and challenging stories. Many pondered the best option to correct this tricky, yet not the most complex congenital heart disease. Some operations that had been replaced by another were later revived. Senning once had been replaced by Mustard as the treatment of choice (Senning, 1959; Mustard, 1964), but was revived because autologous tissue was utilized, although it was more difficult (Quaegebeur, 1977). As people learned the functional implications of the ventricles, both atrial redirection procedures were replaced by the arterial switch operation (ASO) (Jatene et al., 1975; Lecompte et al., 1981; Castaneda et al., 1984). ASO was attempted initially, without transferring the larger right coronary artery, by Mustard (Mustard et al., 1954). Nikaidoh described aortic translocation, which in essence is an ASO including the arterial valve (Nikaidoh, 1984). In the past, few practiced this procedure because of its demanding techniques and potentially worse outcome. However, aortic translocation has recently gained popularity as an alternative to the Rastelli operation and Reparation l'etage ventriculaire (REV) as the treatment for TGA with a left ventricular outflow obstruction (Rastelli, 1969; Yeh et al., 2007; Emani et al., 2009). ASO has become the procedure of choice for TGA (Prêtre et al., 2001; Losay et al., 2002). However, TGA is considered to be a mere reversal of the great arteries anteroposteriorly (Shaher, 1964; Van Mierop, 1971); nonexistence of the normal spiral relationship of the great arteries in TGA has not been widely appreciated. Thus posterior pulmonary bifurcation is mobilised anteriorly to the aorta (the so-called Lecompte maneuver) in an effort simply to reverse transposed great arteries (Lecompte et al., 1981). We proposed an arterial Senning operation 13 years ago, to restore the spiral flow of nature in TGA (Chiu et al., 2000b; Chiu et al., 2002b, Chiu et al., 2010). The role of this operation is still uncertain and it requires continued refinement and development. The thinking process and evolving technique behind how we conceived our currrent technique was published (Chiu et al., 2001). Briefly, mobilization of the pulmonary arteries high above its original site to avoid compression the high take off coronary artey will result in supravalvular pulmonary stenosis (PS), similarly, Lecompte maneuver mobilized pulmonary arteries away from its original position. To avoid the complications of unnecessary mobilization, an *in situ* transfer technique and the common wall concept to redirect the coronary arteries should also be applied to the pulmonary arteries (Chiu et al., 2000b; Chiu et al., 2001). Tissue deficiency of the pulmonary outflow tract in cyanotic cardiac defects could be recruited from the larger aorta to compensate for the smaller main pulmonary artery (MPA); or vice versa, from the big MPA to a small aorta. We called this the Robin Hood approach or, in the current vernacular, a redistributive approach (Chiu et al., 2009). In this review, we describe an innovative technique to reconstruct the great arteries in spiral fashion, which is the natural relationship of aorta and pulmonary artery. The structural and functional studies underlying the basics of natural spiral great arteries we published in the last two decades will be presented. We emphasize the surgical principles of nature and even distribution, using autologous tissues. Anatomical features will be discussed first, then the technique of the above two redistributive approaches in TGA and finally their three-dimensional CT follow-up results.

2. Anatomical features

Transposition of the great arteries is the consequence of distal fusion between the dorsal protrusion of the aortic sac and the outflow cushions during embryogenesis (Figure 1) (Van Praagh, 2010). The conal septum and great arteries remain straight and parallel instead of being torsaded around each other. As a consequence, the aorta emerges from the right ventricle and the MPA from the left ventricle.

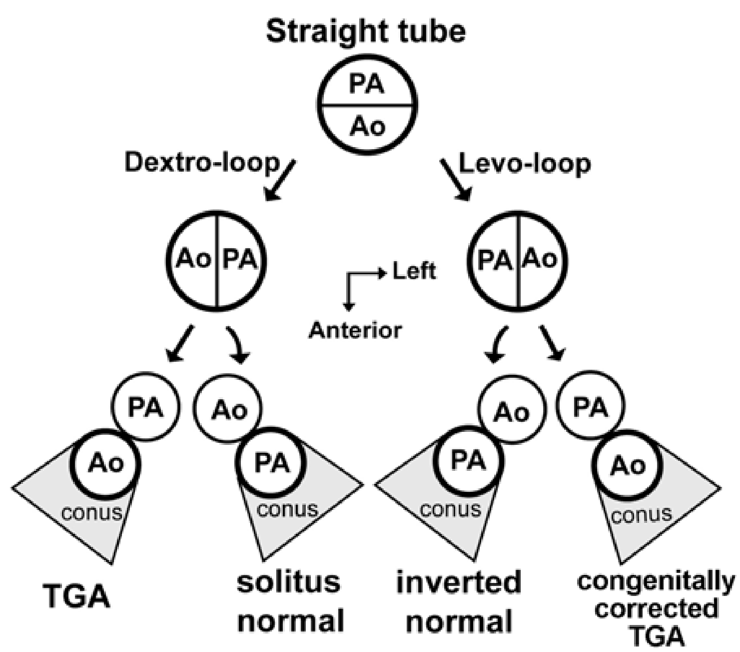

Fig. 1. There are only two ways in which conotruncal rotation can be done correctly as in: (1) solitus normally related great arteries and (2) inversus normally related great arteries; in contrast to many other ways that it can be done wrong.

2.1 Outlet septum

The ventricular outflows are in parallel when there is a side-by-side great arteries. When the aortic root is directly anterior or even left anterior, the outlet septum is no longer in parallel, it is vertical to the rest of the ventricular septum (Chiu et al., 1984). It is often asked that since the outflow tract was not switched and did a spiral ASO offer any help by just restoring the spiral arterial trunks without altering outflow tracts below the valves? Although the ventricular outflow was not switched in spiral ASO, the facing commissure of the old aorta was mobilized along with a topmost outflow below it and fixed it to the direction of future MPA (Figure 1, solitus normal). In other words, by our technique the top portion of the right ventricular outflow just below the facing commissure is rotated toward the direction of future MPA (Chiu et al., 2000b; Chiu et al., 2002b; Chiu et al., 2010). As just clarified, when the aorta is left-sided with usual atrial arrangement, there CAN be spiraling of the outflow tracts; the outlet septum is vertical to the rest of the ventricular septum in the setting with a directly anterior or left anterior old aortic root (Chiu et al., 1984; Anderson & Weinberg, 2005), thus a slight rotation like our technique is adequate for spiral correction at the ventricular outlet in that group. Wheras in side-by-side gruop, Lecompte maneuver is usually not performed by all, the ventricular outflows are in parallel as they are. When the aortic root is right anterior to MPA, we fix the facing commissure to the right anterior aspect of old MPA (Chiu et al., 2000b). The result is as the inverted normal in Figure 1. We did not fix the facing commissure of the new MPA to directly anterior aspect of new aortic root or leave the new MPA alone without fixation, as in conventional ASO, which corrects the ventriculo-arterial discordance without modifying the outflows. *Restoring the natural curvature of both great vessels is the key to avoiding obstruction at the ventricular outflows, instead of just reverse them anteroposteriorly.*

2.2 Coronary artery

Embryologically, the coronary arteries (CA) develop after septation of the aortopulmonary trunk and pierce the aortic sinus at the nearest site after aortopulmonary rotation. We found that the pattern of the CA is dependent on aortopulmonary rotation, thus proposed a new categorization scheme based on the aortic root rotation (Chiu et al., 1995). In addition to the short-axis rotation, which is related to the juxtacommissural origin of the CA (JOCA) (Chiu et al., 1997), there is also a long-axis rotation, which is related to high takeoff of the CA (Chiu et al., 1996b). On the basis of these findings, we have also proposed appropriate diagnostic and surgical techniques to manage unusual CA patterns in TGA (Chiu et al., 1997; Chiu et al., 1996a). In short, for JOCA near the facing commissure, a superiorly based trapdoor (single-button technique) or lateral funnel (two-button technique), and near the nonfacing commissure, a medially based trapdoor, are vital for coronary redirection. The categorization of CA based on the aortopulmonary rotation can be applied to all congenital heart defects and normal hearts (Chiu et al., 2000a; Chiu et al., 2002a; Chiu et al., 2003; Chen et al., 2007; Huang et al., 2011; Chiu et al., 2011).

2.3 Pulmonary artery

Paillole et al. documented the existence of central pulmonary artery (PA) hypoplasia before surgery and its persistence until after ASO (Paillole et al., 1988). Central PA hypoplasia, which is frequently seen in TGA, is related to posterior inclination of the proximal MPA in this setting (Figure 2, Chen et al., 2007). We have demonstrated that the same pathogenesis would lead to smaller PA size after a Senning procedure than ASO with Lecompte maneuver. In addition, Lecompte with Pacifico's modification (direct connection between the distal MPA and the aortic sinus defect), which mobilized the proximal MPA toward anterior aspect farther than by the patch-repair of the sinus defect, could facilitate better PA growth after ASO (Pacifico et al., 1983; Imoto et al., 1995). Spiral ASO would be even better to block that pathogenesis than the above to permit PA growth (Chiu et al., 2010).

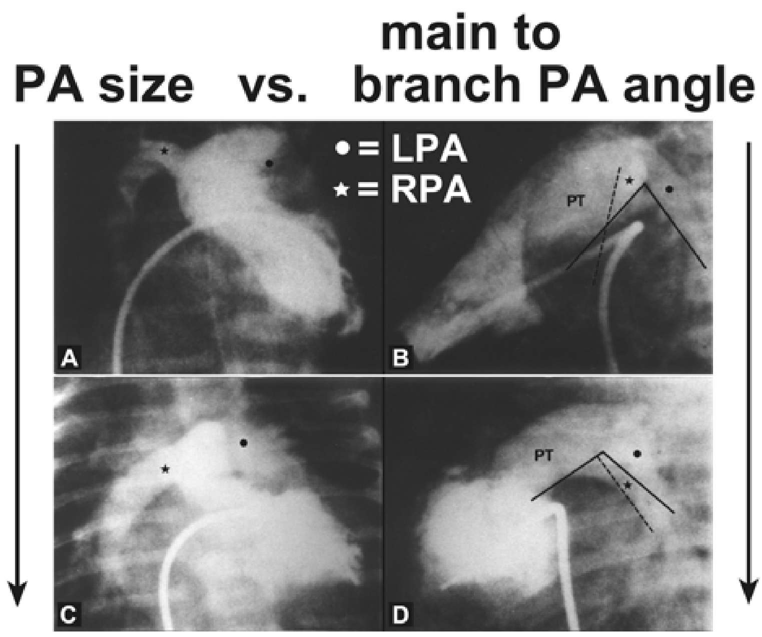

Fig. 2. Our studies on 101 angiograms showed the wider the main to branch PA angle, the better PA size. Narrow L/R PA angle resulted in bilateral PA hypoplasia in the upper panel. Thus wider angle facilitates bilateral PA growth before ASO. Any maneuver that did not correct this inborn error of ventriculoarterial discordance or make even narrower angle like Lecompte maneuver will compromise PA growth.

2.4 Aorta

The aortic arch is kept wide open by the presence of the MPA bifurcation below it (Chiu et al., 2000b; Chiu et al., 2002b). Neo-aortic kinking is the narrowing of the aortic arch window and may become slit-like, can also be called aortic neocoarctation (Figure 3, Chiu et al., 2010; Muster et al., 1987). One group reported an incidence of 0.54% (Serraf et al., 1995). A coarctation is not present and the arch is wide open before conventional ASO with Lecompte maneuver. A pressure gradient across it is rare, less seen than is supravalvular PS because of systemic-pressure in aorta.

Fig. 3. After conventional arterial switch with Lecompte maneuver, a slit like arch window can be seen in the right panel, which was wide open before switch.

We have to take down the "Lecompte maneuver" in a patient eight years after conventional ASO to restore the spiral arterial trunks (Chen et al., 2010).

2.5 Bronchus

The aorta is not the only structure behind the MPA bifurcation after Lecompte maneuver, the left main bronchus (airway-pressure with cartilage) is also present. Bronchial compression or even atelectasis has been reported after Lecompte maneuver (Robotin et al., 1996; Toker et al., 2000), although in the majority of cases the bcronchial patency was not so severely compromised.

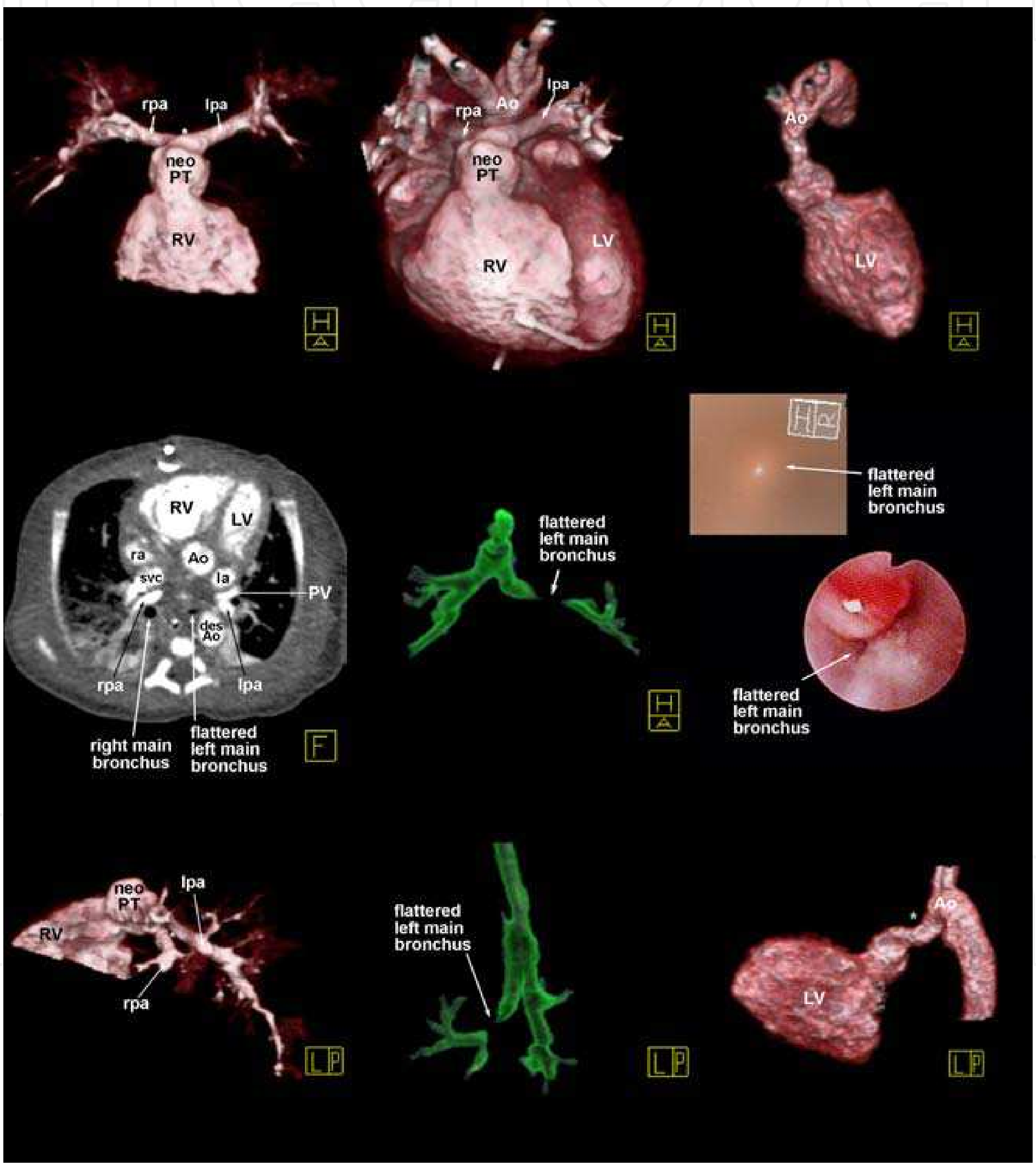

Fig. 4. After conventional ASO with Lecompte maneuver, not only supra-aortic stenosis occurs at the site posterior to the anteriorly mobilized pulmonary bifurcation (*), but also the left main brobchus, that is cartilage stented, is ccompreesed; its lumen becomes pin hole like on brochoscope, both virtual and real. In the right lower panel, the aortic arch window becomes slit-like at lesser curvature site.

3. Surgical management

3.1 Spiral ASO

(Chiu et al., 2000b; Chiu et al., 2002b; Chiu et al., 2010) Figure 5 and 6 showed the techniques that restored the heart to solitus normal in Figures 1, posterior MPA could remain undivided to avoid difficult posterior hemostasis and tamponade, and bilateral hilar dissection was not necessary. In-situ repair will lessen the chance of obstruction.

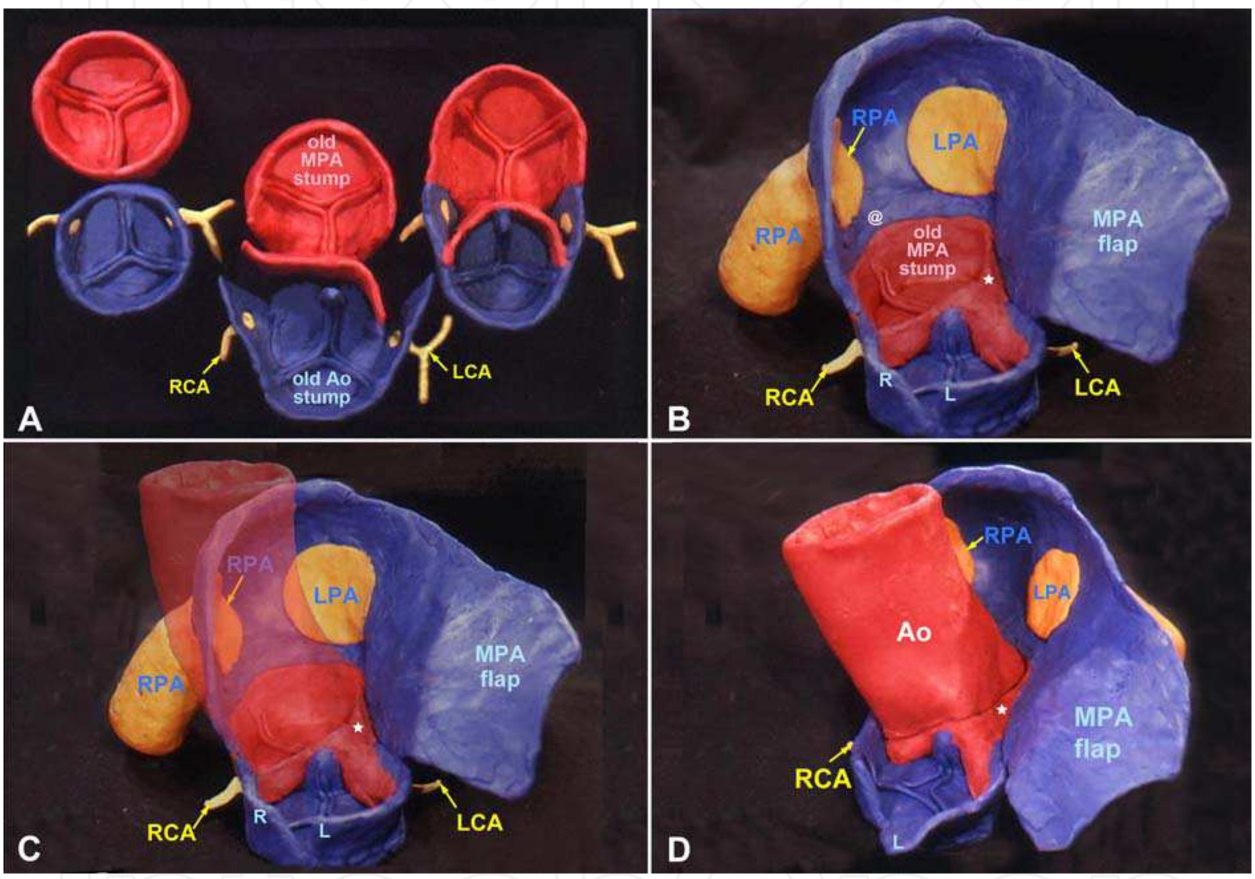

Fig. 5. Technical conceptions for spiral repair (B, C, D). (A) In-situ transfer and common wall were used to redirect the left ventricular output via the old MPA stump into right and left coronary artery (RCA and LCA) as reported (Murthy and Cherian, 1996). Semiflaps were fashioned on the facing sinuses of both great arteies, creating a common arterial trunk that was then septated. Red or blue color in B, C and D indicated the final result after ASO. (B) A big MPA flap was tailored from the MPA. A pericardial patch can be used to augment this flap if the MPA is not large enough. The distal MPA (blue clay) could be reattached to the old MPA stump (red clay), at the neoaortic anastomosis site (blue/red junction marked with @) or proximal to it on the posterior wall of old MPA stump (marked with an asterisk), or remain undivided (in that case blue/red junction indicated site of neoaortic anastomosis); thus, the troublesome posterior neoaortic

Fig. 5. (continued) anastomosis site bleeder can be drained into PAs. Nonfacing sinus was cut open for exposure during coronary transfer. (C) The transparent ascending aorta, with a left aortic lip (procured by oblique amputation of aorta, Chiu et al., 2000b), was rotated counterclockwise to sit on the neoaortic stump. The posterior cut-edge of MPA could be attached to the posterior neoaorta at this stage as leftward as possible.(D) The RPA orifice must be visible behind the aorta to ensure patency of RPA, not just probed with a Hegar dilator. A big enough MPA flap could be reattached to the neoaorta without pericardial patch. (Ao = Aorta, L or R = Left or Right portion of nonfacing sinus wall after cut back, LCA = Left Coronary Artery, LPA =Left Pulmonary Artery, RCA = Right Coronary Artery, RPA = Right Pulmonary Artery)

No-fault transfer of the coronary artery is the cornerstone of a successful ASO. Various techniques (Aubert et al., 1978; Yacoub and Randly Smith, 1978; Kurosawa et al., 1986; Quaegebeur et al., 1986; Brawn and Mee, 1988; Idriss et al., 1988; Bove et al., 1989; Takeuchi and Katogi, 1990; Mee, 1994; de Leval et al., 1994; Murthy & Cherian, 1996; Chiu et al., 1996a & 1997) have been proposed to achieve this goal: de Leval et al. (1994) pointed out that the key point is to take the aorta away from the coronary arteries and the MPA is brought to them, rather than moving the coronaries from the aorta and transferring the coronary scallops to the MPA or neoaorta. To implement this concept, *in situ* transfer technique, proposed by Aubert et al. (1978) and Takeuchi and Katogi (1990), was developed by Murthy and Cherian (1996). This principle is the key (Figure 5) we adopted to redirect the neoaortic outflow tract to the coronary arteries as *in situ* as possible by a common wall concept. In this way the coronary redirection can be achieved more securely than the conventional "coronary transfer".

In situ transfer and the common wall concept not only for the coronary arteries, but also for both great arteries are our guiding principle. We have designed two pedicled grafts, aortic lip and MPA flap, to achieve our goal. The purpose of these two flaps is described below. The aortic lip (Figures 2, 3A and 3B) is initially called left lip (Chiu et al., 2002b). In our first spiral arterial switch, we used a free flap taken from MPA to cover the left-sided portion of the neoaortic stump (Chiu et al., 2000b), to solve the size discrepancy when connecting small aorta to a very large, original MPA stump; the other effect is to act as the floor of the neopulmonic pathway. Since the nonfacing aortic sinus was cut back (Figure 5B and 5C) for exposure during coronary transfer, later we used an aortic pedicled graft including the nonfacing aortic sinus wall (Figure 6A and 6B) to achieve the above 2 purposes of the aortic lip. In addition, using the aortic lip taken from **anterior** sinus wall to cover the **left-sided** portion (Figure 6B and 6C, light blue arrow), we can achieve the effect of counterclockwise rotation of the ascending aorta. This, in turn, would give way to the RPA so that it can sling around the ascending aorta (Figure 6C, Hegar dilator in RPA). The fourth effect of the aortic lip might lessen the chance of coronary kinking by avoiding take-up the larger stump on neoaortic anastomosis, as noted by Quaegebeur et al. (1986).

The purposes of the MPA flap include: (1) accommodating the ascending aorta, (2) achieving a more leftward shift of RPA, and (3) attaching to the ascending aorta without pericardium. Thus, the spiral relationship of the great arteries is resumed by using the autologous pedicled flaps tailored from both arterial trunks, respectively.

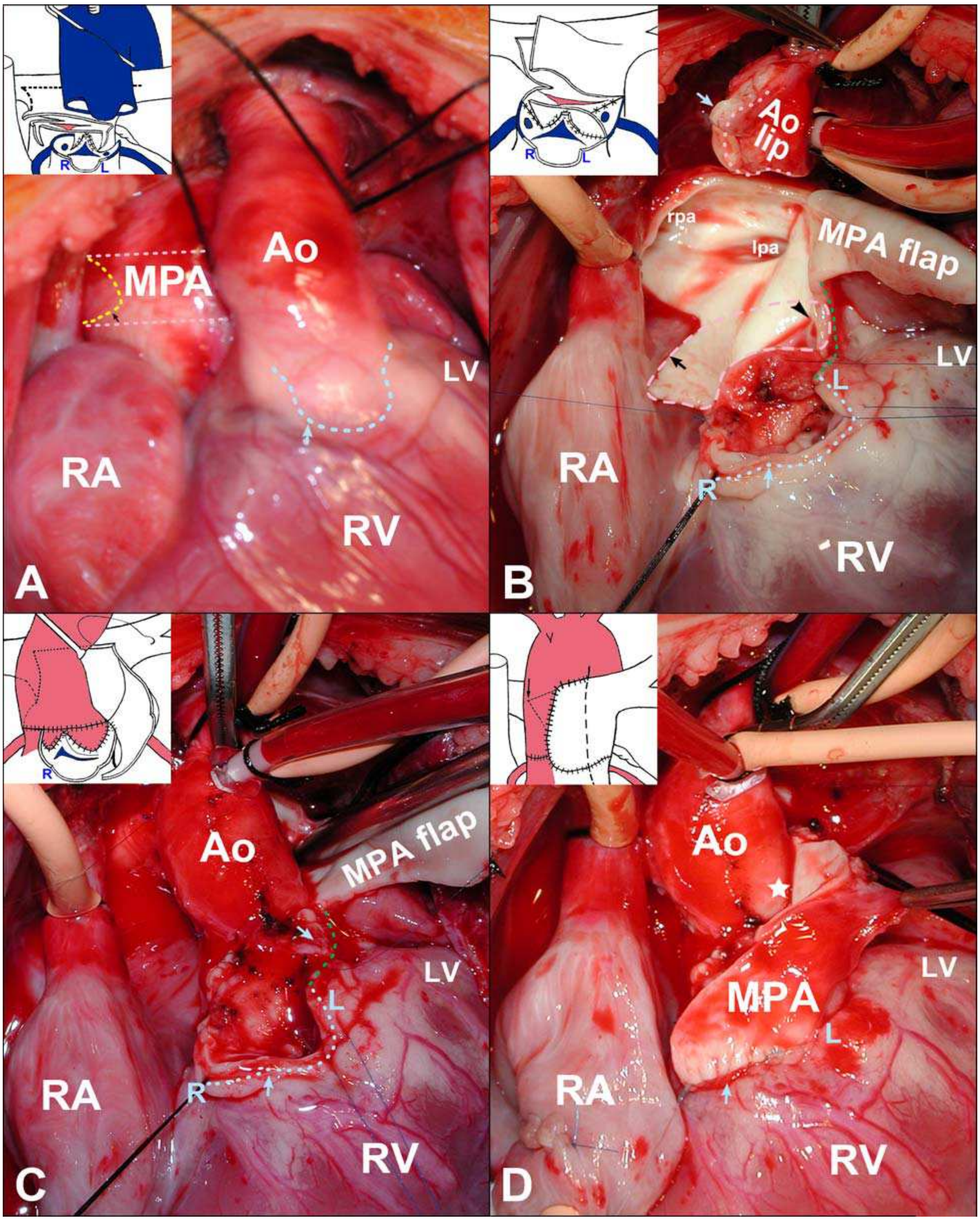

Fig. 6. Operative techniques for spiral ASO with neo-MPA in left anterior portion. Semilunar valves are all omitted for clear illustration in all insets. (A) The aorta is located left anterior to the MPA before ASO. The aortic lip will be taken from the anterior aortic sinus wall along the light blue line on the aorta, an excision that also facilitates exposure on coronary transfer. MPA flap will be incised along the pink dotted line on the anterior MPA, yellow line on the posterior MPA (black arrow) to accommodate the ascending aorta.

Fig. 6. (continued) Left posterior wall of MPA is not divided. Annulus near facing commissure in old aorta is fixed to left anterior wall of MPA (depicted by Y stitches in inset) before incising MPA. Two J-shaped incisions are made to fashion semiflaps on facing sinuses of both great arteries. (B) A big MPA flap can be tailored from the anterior wall of huge MPA, even to its posterior aspect (black arrow, see also inset). Coronary transfer was done, using the technique in Figure 5A. A big aortic lip, redundantly covering the distal aortic orifice in picture, was taken along with the distal aorta during aortic amputation. Pink dotted line along the cut edge of the aortic lip was concordant with the light blue dotted line along the nonfacing sinus wall, and almost the whole nonfacing sinus wall was excised; the light blue arrow indicated corresponding point of the aortic lip originally attached to the aortic sinus. Note the remaining sinus wall on the left (L) and right (R) portion of the remaining nonfacing sinus, and the light blue arrow indicated the same location through the whole Figure 6. One commissure of neoaortic valve is marked with black arrowhead. Neoaorta will sit on the pink dashed line. Aortic lip will cover the left-sided portion of neoaortic stump. (C) The distal aorta was sutured already above the neoaortic valve and coronary to LV outflow. Light blue arrow from anterior to left indicated counterclockwise rotation. Note the Hegar dilator in the RPA. After neoaortic connection and de-crossclamp, the rest of MPA cut-edge near RPA, which was shifted leftward, was attached to the posterior wall of the neoaorta (inset). Caudal edge of MPA flap can be attached at or proximal to cut edge of the old MPA stump and the aortic sinus 1 along the green dotted line (the tissue nearby is more clearly shown in B) and cut edge of the nonfacing sinus wall, which was stay-sutured and indicated here by light blue dots. (D) Attachment to form the floor of pulmonary pathway was finished. The adventitia of the aorta inside the pulmonary pathway (white asterisk) must be peeled off (Chiu et al., 2001; Chiu et al., 2010), because it will be the inner wall of future PA. Cephalic edge of anterior MPA flap can be attached to the outer wall of neoaorta directly (D inset) to roof the pulmonary pathway; ASO can be completed without any pericardial or prosthetic patch, and thus the procedure was named “arterial Senning”. (L or R = Left or right portion of nonfacing sinus wall after excising the aortic lip, LV = Left Ventricle, RA = Right Atrium, RV = Right Ventricle, other Abbreviations see Figure 5)

It would be interesting to see the current status of this patient 7 years after such spiral ASO (Figure 7).

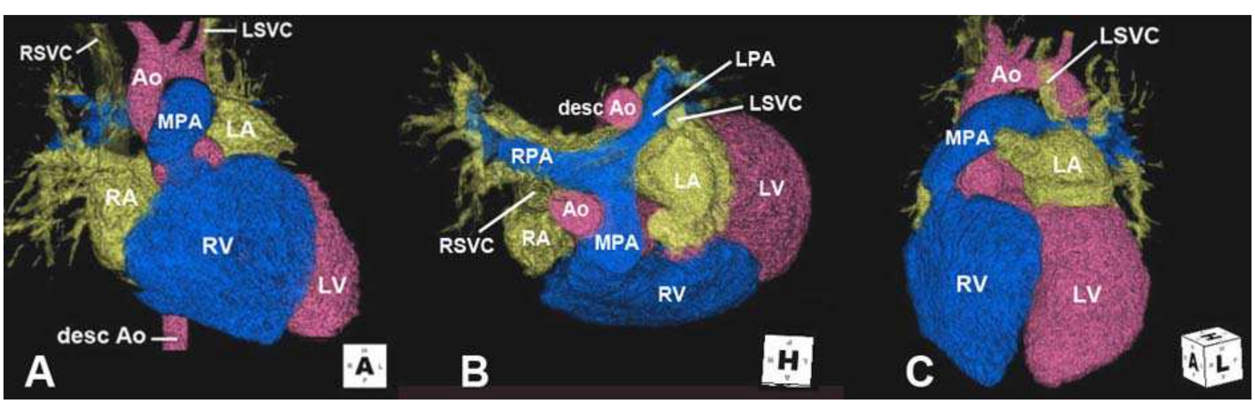

Fig. 7. Three-D CT reconstruction of the patient in Figure 6 seven years after ASO (A, B & C) showed the natural spiral relationship of the great arteries with harmonic growth of their branches. (desc = descending, LA = Left Atrium, R or L SVC = Right or Left Superior Vena Cava, other Abbreviations see Figure 5 & 6. Reproduced with permission from Chiu et al., 2010)

Between March 1998 and June 2011, spiral ASO was performed in 57 patients (38.3%), conventional nonspiral ASO with Lecompte maneuver in 92 patients (61.7%) at our hospital. The median age and weight at operation were 9 days and 3.3 kg. Cross-clamp time was significantly lower ($p < 0.011$) in the spiral than the nonspiral group (128 ± 36 vs 144 ± 37 minutes), because of the common wall technique in spiral ASO, wheras additional time for patch repair on defects in the sinuses of the new MPA was needed in conventional 2-vessel technique. The average follow-up was 6.9 ± 4.2 years (up to 13.5 years). Kaplan Meier survival was 94.1 ± 3.3% at 10 years and the reoperation-free rate 88.3 ± 4.5% for spiral repair. Both ratios were satisfactory and similar to those for the nonspiral group (89.6 ± 3.3% and 89.3 ± 4.1%, respectively). Signicant aortic regurgitatin in the nonspiral group (Chen et al., 2010) was not observed in the spiral group. The supravalvular PS and aortic neocoarctation that occurred in the nonspiral group (7.6% and 2.2 %, respectively) did not occur in the spiral group (0 %) (Chiu et al., 2010); these 2 complications are related to Lecompte maneuver and the unnatural relationship of the great arteries. Tiny aortopulmonary fenestration with a small left to right shunt occurred in 15 cases of spiral group (26.3%), but they closed spontaneously after a median follow up of 6 months by echo. TGA is not merely a reversal of the great arteries; nonexistence of the spiral function in TGA should be appreciated. Recognition of the spiral function and further modification might justify its future application.

3.2 Modified rastelli operation

In complete TGA with left ventricular outflow obstruction, a segment of the aorta is cut in transverse fashion and donated to the pulmonary circulation to establish the ventriculoarterial continuity (Figure 8).

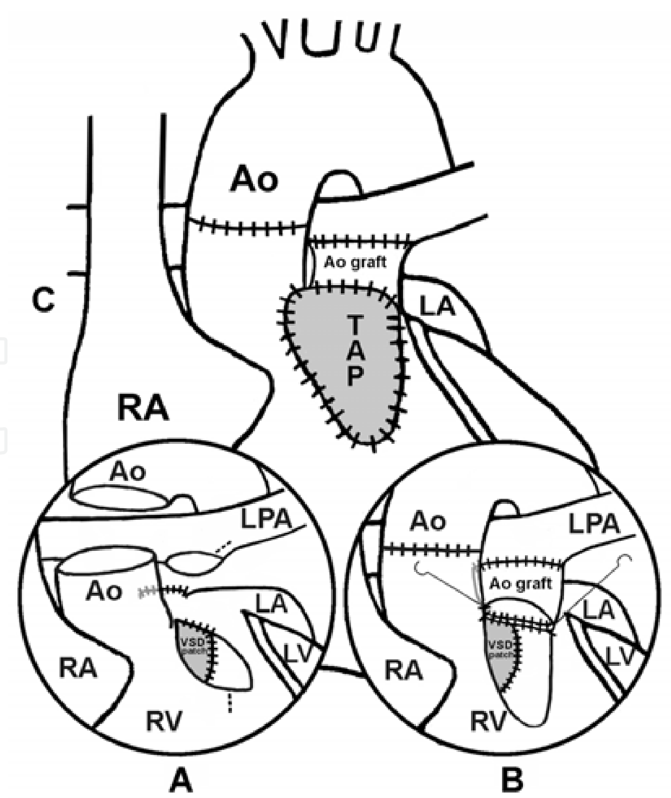

Fig. 8. Operative techniques for TGA with irreparable left ventricular outflow obstruction.

Fig. 8. (continued) The ascending aorta was amputated, and a curved segment (18 mm x 6 mm) was harvested (A) and then reconnected (B). The ventricular septal defect was rerouted to the systemic outflow with a patch. The MPA was divided and the proximal stump was closed. The aortic free graft was sutured to the distal MPA with the greater curvature on the left (B). The lengthened MPA was then connected directly to the cephalic margin of ventriculotomy. Finally, a piece of fresh pericardium was harvested and sutured to cover the right ventricular outflow tract (C). (TAP = TransAnnular Patch, other Abbreviations see Figures 5-7. Reproduced with permission from Chiu et al., 2009)

End to end anastomosis of the ascending aorta after excision of a segment shortened the distance between the right ventriculotomy and the PA, so that the aortic free graft could achieve its bridging effect comparable to the conventional conduit of double length without aortic shortening. This advantage of aortic shortening is also observed in patients undergoing Nikaidoh operation (Morell & Wearden, 2006). We agree with Metras and coworkers (Metras et al., 1997) that Lecompte maneuver to mobilize the pulmonary bifurcation anterior to the aorta is unnecessary. This is because if the pulmonary bifurcation is left *in situ* as it is originally by nature, the chance for developing supravalvular PS may decrease (Chiu et al., 2000b; Chiu et al., 2002b). Our direction for placement of a free graft of this curved aortic segment is opposite to that proposed by Metras (Metras et al., 1997). Follow-up CT showed satisfactory result (Figure 9).

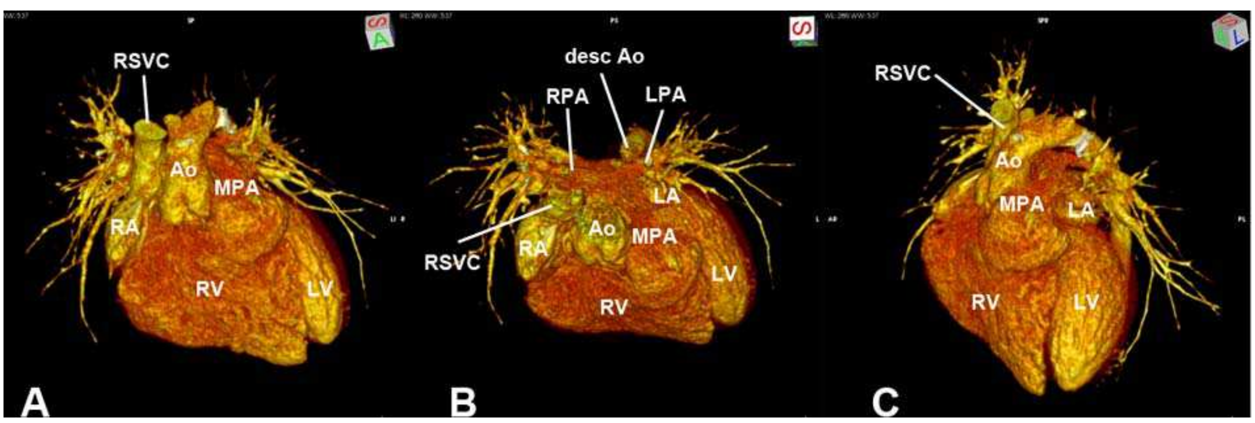

Fig. 9. Three-D CT reconstruction six years after Modified Rastelli operation; no stenosis was observed at the site of free graft. The natural spiral arterial trunks with harmonic growth of their branches were evident. Abbreviations see Figure 7.

A major complication of the Rastelli operation was related to the conduit itself; crossing the midline, conduit dysfunction or valve degeneration might lead to conduit failure early or late after surgery. Our technique of recruiting autologous arterial tissue will avoid these complications and help free the patients from reoperation.

4. Comment

The natural spiral relationship of the great arteries and their branches can grow on follow-up (Figure 7 and 9). We have demonstrated that the common wall between the great arteries could grow and become thinner on follow-up (Chiu et al., 2009). Spiral reconstruction in TGA is seldom performed, because the functional implications of spiral relationship of the great arteries remain unknown; thus, the Lecompte maneuver was used either in conventional ASO or Nikaidoh and Lecompte (REV) operation (Emani et al., 2009; Morell & Wearden, 2006;

Lecompte et al., 1982). Review of surgical treatment for TGA reveals that once the functional implications of two normal ventricles were well known, nobody selected the right ventricle as the systemic pumping chamber. The rationale of spiral reconstruction (Figure 10) at the great arterial and ventricular level includes (1) widening of arch window to avoid aortic neocoarctation (Figure 3), (2) widening of main to branch PA angle to facilitate PA growth (Figure 2, Chen et al., 2007), and (3) avoiding PA compression by the aorta posteriorly.

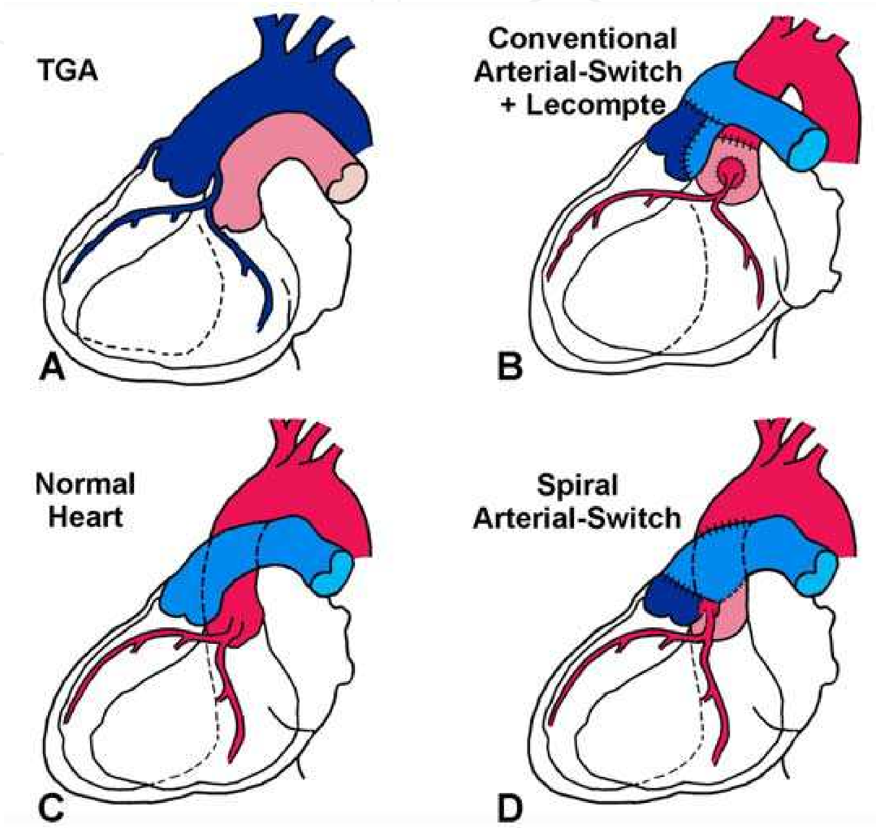

Fig. 10. Spiral relationship of the great arteries in normal heart (C) was not restored by conventional ASO with Lecompte maneuver (B) on TGA (A). With spiral ASO (D), pulmonary bifurcation is free from posterior compression by high-pressure aorta. Note that acute angulation of arch that is present after Lecompte maneuver (B) is absent in other three illustrations. Acute angulation from the main pulmonary artery to its branches is also present in A and B, but not in C and D, in which main to branch pulmonary artery angle is wider and smoother. Reprinted with permission from Elsevier (Eu J Cardiothorac Surg 2010;37:1239-45).

To facilitate PA growth, mobilise the posterior inclination of the proximal MPA and restore its 'normal' position (Figure 10C) to direct a natural and smooth blood flow into the PA in the neonatal period is the surgical principle. Thus widening this acute angle to both PA in spiral fashion (Figure 10D) is more helpful than the Lecompte maneuver with a huge patch (Figure 10B) for promoting PA growth (Norwood et al., 1988; Paillole et al., 1988; Lupinetti et al., 1992). The systemic high-pressure ascending aorta may compress the neo-MPA from its posterior end towards its anterior end. Insufficient dissection of the distal PAs was suggested to explain this flattened (oval-shaped) MPA in 1988 (Wernovsky et al., 1988), but a later study showed that the cross section of the MPA is still flattened 6 to 22 months after conventional ASO with hilar dissection and the Lecompte maneuver (Massin et al., 1998).

After the Lecompte maneuver, not only flattened anterior MPA (low-pressure), branch PA stenosis, and supravalvular PS at pulmonary bifurcation can occur as a consequence of posterior compression of MPA by the ascending aorta (Williams et al., 1997; Gutberlet et al., 2000); but also the aorta itself (systemic-pressure) may be compromised. Therfore, aortic neocaorctation was reported (Muster et al., 1987; Serraf et al., 1995).
Most interestingly, we used computational fluid dynamics on mathematic modeling to compare flow phenomena of the spiral and nonspiral models (Figure 11). The functional superiority of the spiral over the nonspiral model is demonstrated because the blood flow inside is more streamlined andthere is a smaller power loss ratio (Tang et al., 2001).

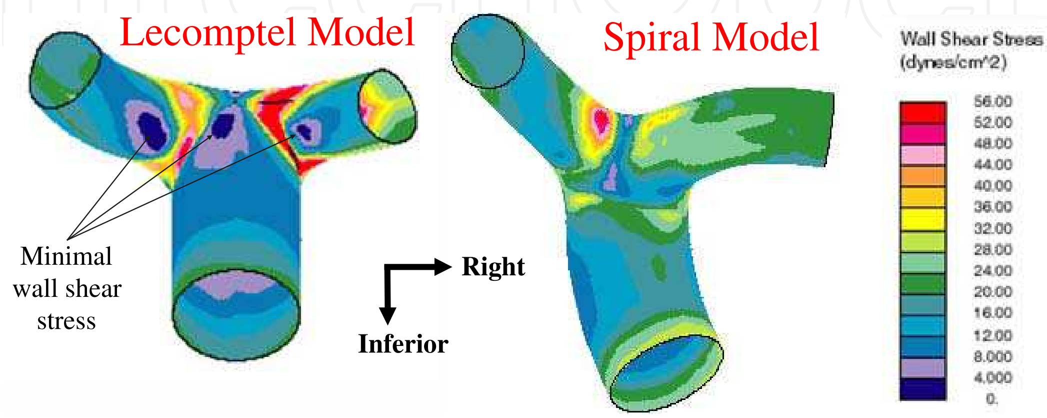

Fig. 11. The regions of minimal wall shear stress in purple color in the left panel are the site where supravalvular PS is prone to occur. On the contrary, there is no purple color in spiral model. Wall shear stress is more uniform and the blood flow is more in streamline.

Spiral reconstruction would be beneficial to reduce supravalvular PS (Figure 10), supra-aortic stenosis (Figure 4), and aortic neocoarctation (Figure 3 & 10). This is to say, the great arteries are normally in a spiral fashion, thus the MPA bifurcation avoids being compressed by the aorta, and the arch window is kept wide open by the adjacent pulmonary bifurcation.
Potential limitations of our proposal merit consideration. First, the number of cases studied is small. Second, this is aretrospective study, and longer-term follow-up is mandatory to ascertain the benefit or possible drawbacks of spiral ASO over non-spiral ASO. Subvalvular PS still occurred, but mainly related to infundibular hypertrophy, and not supravalvular as in the non-spiral group. Subvalvular PS was probably related to an unusual coronary artery traversing the infundibulum (Chiu et al., 2010), which may be associated with a thick subaortic muscle bundle that can produce subpulmonary narrowing after ASO (Kurosawa, 1991).
It might be questioned whether our technique will reproduce the old dire complicarions that was avoided by Lecompte maneuver such as compression on the transferred coronary arteries (Chiu et al., 2010, discussant). Acually secure coronary redirection like our method is more important than a mere absence of a near-by low-pressure vessel like pulmonary artery. The so-called complications are not seen in our series. Any method that redirect coronary safely can be done in combination with spiral arterial trunk reconstruction.
Our previous publications (Chiu et al., 2000b; Chiu et al., 2002b; Tang et al., 2001) were cited by Dr. Corno at the 86th annual meeting of American Association for Thoracic Surgery, in a symposium about the potential implications of the helical heart to congenital heart disease (Corno, 2006a; Corno, 2006b). In 2001, following we presented our spiral arteial switch at National Cardiovascular Center in Osaka, Japan, Dr. Hideki Uemura named our procedure as "arterial Senning". He is affiliated now with Royal Brompton Hospital in London, UK.

We are grateful to his thoughtful nomenclature for our procedure. We dare not call the spiral arterial switch this name by ourselves before his proposal.

5. Conclusions

The concept of *in situ* transfer and common wall technique should be applied to redirect not only the coronary arteries but also the PAs and the aorta in TGA. Thus, tamponade, coronary events, supravalvular PS, and aortic neocoarctation can be prevented and natural spiral flow can be restored. Study of TGA and its natural or secondary natural history provides a means to understand the functional implications of the normal cardiac anatomy. As said by Einstein: "All our science, measured against reality, is primitive and child-like and yet is the most precious thing we have." How to restore TGA as much as possible to resemble its natural and unique likeness, awaits further modification and continued effort to conceive more surgical options in the coming half-century. Those stick to the surgical principle of nature and even distribution using autologous tissues, although more difficult and technically demanding, will be revived again and again, as shown by examples such as Senning versus Mustard, arterial switch versus atrial redirection, Nikaidoh versus Rastelli, arterial Senning versus arterial Mustard----etc.

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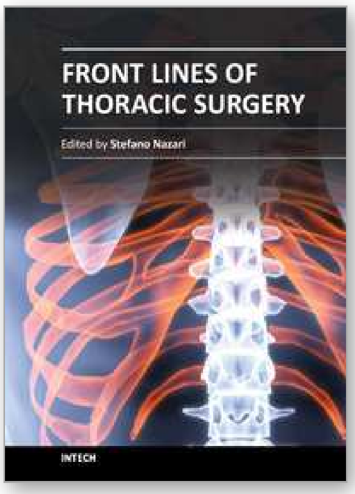

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Front Lines of Thoracic Surgery collects up-to-date contributions on some of the most debated topics in today's clinical practice of cardiac, aortic, and general thoracic surgery,and anesthesia as viewed by authors personally involved in their evolution. The strong and genuine enthusiasm of the authors was clearly perceptible in all their contributions and I'm sure that will further stimulate the reader to understand their messages. Moreover, the strict adhesion of the authors' original observations and findings to the evidence base proves that facts are the best guarantee of scientific value. This is not a standard textbook where the whole discipline is organically presented, but authors' contributions are simply listed in their pertaining subclasses of Thoracic Surgery. I'm sure that this original and very promising editorial format which has and free availability at its core further increases this book's value and it will be of interest to healthcare professionals and scientists dedicated to this field.

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