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Surgical management and indication of left ventricular retraining in arterial switch for transposition of the great arteries with intact ventricular septum ☆

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Abstract

Objective: Arterial switch is the operation of reference for the surgical treatment of transposition of the great arteries. In cases of late referral, perinatal complications or early left ventricular (LV) dysfunction, the one stage arterial switch is contra indicated. Anatomical repair remains possible in these patients following a LV retraining. **Methods**: From January 1992 to January 2000, a LV retraining was attempted in 22 patients with transposition of the great arteries with intact ventricular septum (TGA IVS), whereas 470 direct arterial switch and 2 Senning were performed. Indication for LV retraining was based on a combination of factors including: an age older than 3 weeks, a 'banana shape' aspect of the inter-ventricular septum and mainly a LV mass $<35G/m^2$. **Results**: The mean age at LV retraining was 3.2 months ranging from 9 days to 8 months. Usually conducted by sterntomy, it associated a loose PA banding with a LV/RV at 65% with a systemico-pulmonary shunt. The first stage was associated with frequent LV dysfunction and the LV retraining was discontinued in two patients in favor of one Senning and one early switch followed by ECMO. One patient died at first stage from a mediastinitis. Nineteen patients underwent a second stage arterial switch that was performed when the LV mass had reached 50 G/m^2 after a mean delay of 10 days, ranging from 5 days to 6 weeks. After a mean follow up of 25 months, there was one non-cardiac late death. The 17 patients followed and leaving with an arterial switch are in NYHA class I, with a mean LV shortening fraction of 39%. **Conclusions**: Arterial switch following LV retraining in TGA IVS is a satisfactory option. The inferior limit of 35 G/m^2 adopted, to indicate LV retraining, seems a safe landmark. The quality of the myocardium generated and the respective roles played by the LV afterload, LV wall shear stress, LV inflow and outflow to induce the LV remodeling remain under debate.

Keywords: Congenital heart diseases; Cardiac surgery; Transposition of the great arteries; Arterial switch; Left ventricular retraining

1. Introduction

Arterial switch is nowadays the operation of reference for the surgical treatment of transposition of the great arteries [1]. The left ventricle (LV) ability to sustain a systemic function is slowly decreasing after 2 weeks of age in TGA-IVS (transposition of the great arteries with intact ventricular septum) and depends upon the patency of the ductus arteriosus, the level of the pulmonary resistances, the size of the atrial septal defect (ASD) and the presence of a left ventricular outflow tract (LVOT) obstruction. LV retraining in TGA-IVS was first reported by Yacoub [2] in 1977 before the era of the neonatal switch. In 1989 Jonas [3] reported the rapid two stage switch technique.

Several aspects remain under debate regarding the LV retraining in TGA-IVS:

- the left ventricular 'landmarks' indicating LV retraining.
- the optimal methods of LV retraining allowing to decrease the morbidity associated with the first stage.
- the quality of the hypertrophied myocardial tissue generated and the upper age limit.

The aim of this article is to attempt answering these points in looking at a retrospective series of 22 patients who underwent a LV retraining for TGA-IVS.

2. Patients and methods

From January 1992 to August 2000, 22 patients with

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Table 1

LV Mass (ASE) = 1.04 * (LVED d + LVPW d + IVS d)^3 − LVED d^{3a}
Indexed LV Mass (G/m^2 = [0.8 * (LV Mass) to 0.6] / BSA

[a] LVED d, left ventricle end diastolic diameter; LVPW d, left ventricle posterior wall thickness; IVS d, left ventricle interventricular thickness; ASE, American Society of Echography.

TGA-IVS or virtually closed VSD underwent a left ventricular retraining. In the same period, 470 direct arterial switch and two Senning were performed for TGA-IVS.

2.1. LV myocardial mass evaluation

The LV myocardial mass was calculated at TM echocardiography. The formula issued by the American Society of Echography was used [4] (Table 1); the mass was then indexed and related to the body surface area. The measurements were all made by a single pediatric cardiologist (using Acuson 128 × P, Acuson Corporation). The measurements of the end diastolic LV diameter, the posterior wall and inter-ventricular thickness were performed in long axis parasternal view and the formula was calculated using an algorithm available in the echocardiography machine.

There are two limitations for this formula. The calculation is an approximation of a spheric volume. The variation of the LV shape induced by the variation of the LV volume might have a consequence on the calculated mass.

An indexed LV mass of 35 G/m^2 was taken as inferior limit to indicate LV retraining in the majority of the patients.

2.2. Indication for LV retraining

LV retraining was indicated according to a combination of different factors: mainly the indexed LV mass but also the age >3 weeks, the inter-ventricular septum shape and the various presence of an ASD, a patent ductus arteriosus and a LVOT obstruction.

An indexed LV mass of 35 G/m^2 was taken as the inferior limit to indicate LV retraining in the majority of the patients. The median LV mass was 28 G/m^2 ranging from 12 to 33 G/m^2 (Fig. 1). Eight patients had a LV mass less than 20 G/m^2.

The median age at palliation was 3.2 months ranging from 9 days to 8 months. Seventeen patients were older than 3 weeks. Two patients were less than 2 weeks: both had reduced LV mass, respectively 16 and 20 G/m^2. Three other patients were seen early but the arterial switch was postponed because of perinatal complications including: one meningal hemorrhage, one lung infection and one presternal burn. Two patients, one with a relatively large muscular VSD and another one with multiple muscular VSD were seen at a time when the VSD were virtually closed and when the LV mass had severely decreased.

All patients had a right to left bulging of the inter-ventricular septum with a 'banana' LV shape at 2D echo-cardiography.

Two patients had some degree of LVOT obstruction with systolic gradient less than 20 mmHg. All patients had an ASD that was judged small in 5 patients. Eight patients had a previous Rashkind septostomy. One patient had a patent ductus arteriosus.

2.3. First stage

The palliation was conducted through sternotomy in 16 patients and through right thoracotomy in 6 patients. The systemico-pulmonary shunt was first done using a Gore Tex shunt including: 15 × 3.5, 5 × 4 and 1 × 5 mm. The shunt was smaller when the ASD was restricted. Under a FIO^2 of 30%, the Goretex shunt was opened and the hemodynamics stabilized. The pulmonary artery banding was placed distant to the pulmonary valve. The banding ligature was attached to the pulmonary trunk adventicial tissue. It was loosely tighten to obtain a LV/RV systolic pressure ratio between 65 and 75%, in measuring the LV pressure by direct punction. The anterior pericardium was respected and it was then partially closed.

Inotropic support was always required, including variously: Dopamine, Milrinone, Adrenaline. It was based on the LV function evaluated on repeated surface echocardiography.

2.4. Results first stage

The post operative course of the patients, following the first stage was associated with a significant morbidity, in relation with the LV adaptation. The sudden increase of the LV afterload, of the parietal wall stress and of the QP/QS creates in the majority of the patients a significant LV dysfunction that can be severe leading to a stunning of the LV with the only RV contracting, comparable to a single ventricle circulation. Two third of the patients showed a severely decreased LV shortening fraction less than 20%. In four patients it was required to leave the sternum opened.

One patient died from a severe mediastinitis.

In two patients, the LV retraining was stopped because of untractable LV failure. One patient had a Senning in the following weeks. The other patient, who exhibited a bi-ventricular stunning, had an emergency switch followed by 5 days of ECMO. These two patients survived these procedures.

Six patients required to be reoperated in the immediate post operative course for four shunt revision and three PA banding judged too tight. More recently, the respect of a LV/RV ratio around 65% to loosely tight the banding was associated with a stable hemodynamic.

2.5. Second stage

The arterial switch was performed when the LV mass, evaluated at repeated echocardiography, had reached 50

G/m^2. The median delay between the first and second stage was 10 days, ranging from 5 days to 6 weeks. It was noticeable that the muscle production was explosive in some patients leading to a rapid massive hypertrophy of the LV.

The second stage arterial switch, performed in 19 patients, was technically more difficult because of the presence of adhesions. The reading of the coronary arteries course and the mobilization of the pulmonary branches required particular attention.

There was no mortality at repair and the post-operative course was easier than in a one stage switch, in relation with the excellent LV mass present.

During the same period, 12 patients with an LV mass between 20 and 30 G/m^2 underwent a direct arterial switch with two failures (one death and one ECMO).

2.6. Follow up

The mean follow up is 25 months ranging from 4 months to 8 years. Three oversea patients are lost to follow up. There was one non-cardiac death, occurring 6 months after the operation, in North Africa, from pneumonia.

All the 17 patients surviving and followed patients leaving with an arterial switch are in NYHA class I, without medication and physical limitation. The mean LV shortening fraction is 39%.

3. Discussion

This series reports an experience of LV retraining in TGA IVS. The remodeling of the neonatal and infant myocardium is a major issue of research where surgical research is closely associated with biological and genetic myocardial research. The respective role of afterload, shear stress, inflow and outflow stimuli that induce growth or involution of the ventricular cavities are nowadays poorly defined. Similarly the quality of the myocardial tissue generated remains unknown.

3.1. Improvement in LV function evaluation.

The rule followed in our Institution before 1990 [1] was that below 3 weeks of age, the risk of ventricular dysfunction was minimal; provided that the ductus arteriosus was maintained opened by Prostaglandin. The LV availability to sustain systemic function relied mainly on the inter-ventricular septum shape, as described by Sidi et al. [6]. A bulging left to right or a flat septum indicates that the LV pressure remains at an acceptable pressure, whether a bulging right to left, with a 'banana shape' ventricle indicates that the LV pressure is quite low and that the LV preparation is questionable. In fact, the interventricular septum shape reflects only the pressure gradient between the ventricles and is finally related mainly to the LV afterload and the pulmonary resistances. The interventricular septal shape method is unable to define the remaining suitability of the LV myocardium. When the LV pressure is maintained, it is assumed that the LV myocardium is still facing a significant afterload and will probably not lose its strength. But at the opposite, when the LV pressure is low, in presence of a 'banana shape' septum; the LV is loosing its 'musculation' because of decreased afterload stimulus, but could possibly remain suitable. At what time, the LV has definitely lost its ability to sustain a systemic function is an unanswered question. In absence of objective values, there has been a wide range of answers. Some suggested to perform arterial switch in the first week of age [7] and others suggested that it was possible until 2 months of age [5,8]. In fact the ability of the LV to maintain sufficient myocardial strength seems very different from one patient to another.

After 1990, the LV function has been evaluated more objectively. Following the rapid two stages arterial switch experience [9] and the possibility of directly measuring LV end diastolic (LVED) volume and LV mass in using algorithms available in the echocardiographic machines, the LV function was more precisely evaluated.

3.2. LV myocardial mass value.

The LV ability to sustain a systemic pressure depends on several factors. The LV mass represents an autonomous myocardial value that should be independent of LVED volume, afterload and mitral flow. In fact the calculation of the LV mass is not independent of LVED volume and for the rare cases of decreased LVED volume that are seen in TGA IVS, the LV mass decrease is probably over-evaluated. The indexed LV mass is an approximation of a spheric calculation [4] that can have limitation.

The inferior limit used to indicate LV retraining has been 35 G/m^2. This value is quite arbitrary and can be discussed. Nevertheless, it was a satisfactory landmark in our clinical practice.

3.3. Landmark for indicating LV retraining in TGA IVS

The indication of LV retraining was taken on a combination of factors including an age greater than 3 weeks, a 'banana shape' inter-ventricular septum and mainly a LV mass <35 G/m^2.

All patients had 'banana shape' inter-ventricular septum.

Five patients were less than 3 weeks of age. Three of them had normal LV mass but were not operated because of peri-natal complications. Once these complications cleared, a two stage program was applied. It was obvious in our total series of arterial switch [1] that peri-natal complications were a risk factor for arterial switch mortality.

Two other patients, seen before 2 weeks had an LV mass calculated respectively at 16 and 20 G/m^2. These patients had also a decreased LV volume.

The two failures seen out of 12 direct ASO performed on patients with LV mass between 20 and 30 G/cm^2 allow to evaluate the potential risk observed when undertaking arter-

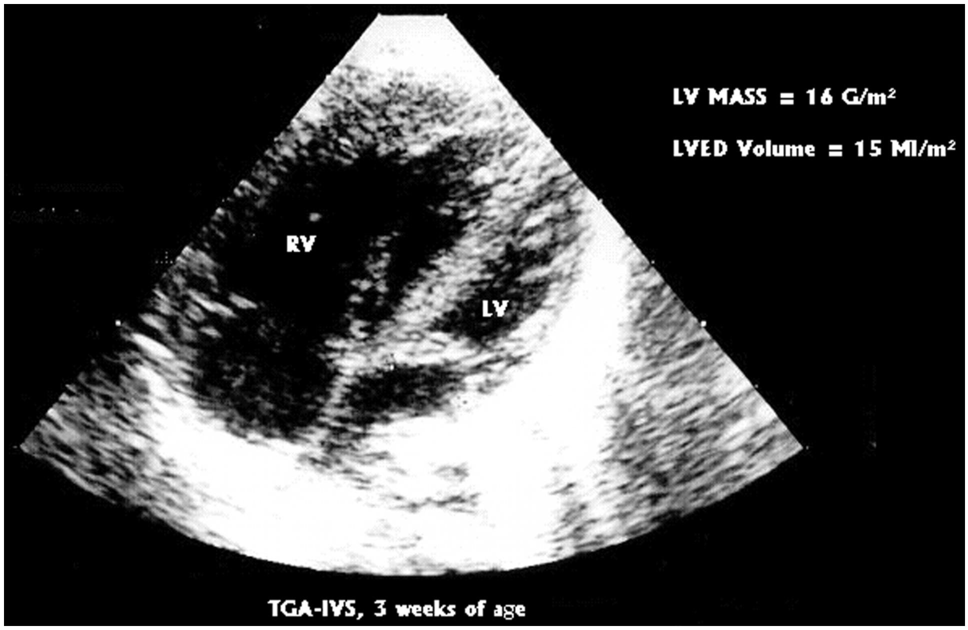

Fig. 1. TGA IVS, 3 weeks of age.

ial switch, in our Institution, below the mass value of 35 G/ m^2.

For Foran et al. [5], primary ASO in TGA-IVS is the appropriate treatment for infants up to 2 months of age, regardless of pre-operative echo-cardiographic variables.

Two patients had closing VSD, including one with muscular VSD. The natural evolution of many peri-membranous and muscular VSD are to close spontaneously. Delaying arterial switch in presence of mid size VSD is taking the risk that the VSD diameter decreases and that the LV becomes unprepared.

Following the LV pressure drop in TGA-IVS, the ventricular septum is shifted to the left and can create a LVOT obstruction. The LVOT gradient can be elevated and even maintains a sufficient pressure in the LV to allow arterial switch. Such a clinical picture was observed in another two patients, not presented in this series, where a direct arterial switch was performed successfully after 3 weeks of age; the inter-ventricular septum shifting back from left to right after the arterial switch. The upper age limit, that allows a backward shifting of the septum without organic LVOT obstruction (LVOTO) remains to be defined.

3.4. Morbidity of the first stage

The LV retraining was associated with a significant morbidity and failed in two patients.

The application of a PA banding induces a sudden increase of the afterload leading to an increased LV wall shear stress. The addition of a systemico-pulmonary shunt increases the pulmonary flow with a QP/QS >1 that increases the mitral inflow. The respective roles of these stimuli to induce the LV myocardial remodeling is unknown. But the immediate consequence on the LV function is quite deleterious with severe complications observed. Too a tight PA banding is to be avoided as early pointed by Ibawi et al. [10]. An important shear stress applied on the LV endocardium can probably induce subendocardial ischemia with major LV function impairment, as it was observed in several patients. Tightening moderately the PA banding with a LV/RV ratio at 65% allowed to prevent LV dysfunction in allowing LV remodeling in the same time frame. In two patients the retraining was interrupted.

3.5. ECMO versus LV retraining

It has been successfully proposed [11] to use post-operative ECMO instead LV retraining in 'unprepared ' TGA IVS. It is clear that post operative ECMO represents an alternative method of LV retraining as it was used successfully in one patient in this series. Nevertheless, ECMO remains logistically an heavy procedure associated with an elevated cost in relation with the technical staff required, the expensive long-lasting oxygenator membrane and the important quantity of blood products required to control the obligatory blood lost. So far, we have used ECMO more as a rescue method than an elective indication. A well conducted LV retraining applied for a period of 10 days, seems in our experience more adapted.

3.6. Quality of the myocardium generated

If the clinical status of the 17 patients followed is satisfactory, with a mean LV shortening fraction at 39%, at 25 months of mean follow up, more precise evaluation particularly at effort is required to confirm the good clinical impression. Nevertheless, it is not confirmed that the quality of the myocardium generated is similar to a native not retrained myocardium.

The ability of the ventricle to undergo hypertrophy or hyperplasia in response to changes in volume or pressure overload is transitory. Within weeks after birth, the myocyte can no longer undergo mitosis resulting in a fixed number of myocytes [12]. After this time, the heart can hypertrophy in response to a physiological challenge, but may do so in an ultimately maladaptive fashion [13]. These cellular changes are reflected in molecular alterations. Contractile and structural proteins, endocrine molecules, ion channels, and regulatory networks respond to both physiological stressors and normal development. Contractile protein isoforms have been studied in Tetralogy of Fallot with modulation of myosin light and heavy chain isotypes [14]. However, determining if changes are primary or secondary to another process requires the ability to genetically manipulate animals. This has been demonstrated in a number of different situations, e.g. adrenergic receptors [15], calcium handling proteins [16] and contractile proteins [14].The ability to manipulate these molecules in spatial and temporally specific manners are presently key aspects in understanding the pathophysiology of maladaptive growth responses. Manipulation of these molecules may also help ameliorate these problems in the future.

An upper age limit is suspected to successfully remodel the LV in TGA [13]. The experience in retraining TGA IVS following failing atrial switch is in favor of an upper age limit that is not defined [17].

References

[1] Planché C, Lacour-Gayet F, Serraf A. Arterial switch. Pediatr Cardiol 1998;19:297–307.

[2] Yacoub M, Radley-Smith R, Maclaurin R. Two stage operation for anatomical correction of TGA-IVS. Lancet 1977;1:1275–1278.

[3] Jonas RA, Giglia TM, Sanders SP, Wernovski G, Castaneda A. Rapid two stage arterial switch for TGA IVS beyond the neonatal period. Circulation 1989;80(Suppl. I):203–208.

[4] Devereux RB, Alonso DR, Lutas EM, Gottlieb GJ, Campo E, Sachs I, Reichek N. Echocardiography assessment of LV hypertrophy: comparison to necropsy findings. Am J Cardiol 1986;57:450–458.

[5] Foran JP, Sullivan ID, Elliott MJ, de Leval MR. Primary arterial switch operation for TGA IVS in infants older than 21 days. J Am Coll Cardiol 1998;31:883–889.

[6] Sidi D, Planché C, Kachaner J, Villain E, Lacour-Gayet F. Anatomic correction of simple TGA in 50 neonates. Circulation 1987;75:429–435.

[7] Castaneda AR, Norwood WI, Jonas RA, Colan SD, Sanders SP, Lang P. TGA IVS: anatomical repair in neonates. Ann Thorac Surg 1984;38:438–443.

[8] Davis AM, Wilkinson JL, Karl TR, Mee RB. TGA IVS arterial switch repair in patients 21 days of age or older. J Thorac Cardiovasc Surg 1987;94:87–94.

[9] Boutin C, Jonas RA, Sanders SP, Wernosvki G, Mone S, Colan SD. Rapid two stage arterial switch operation. Acquisition of LV mass after PA banding in infants with TGA IVS. Circulation 1994;90:1304–1309.

[10] Ibawi MN, Idriss FS, DeLeon SY, Muster AS, Duffy CE, Paul MH. Preparation of the left ventricle for anatomical correction in patients with simple TGA. J Thorac Cardiovasc Surg 1987;94:87–94.

[11] Naughton P, Mossad E. Retraining the LV after ASO: emerging uses for the left ventricular assist device in pediatric cardiac surgery. J Cardiothorac Vasc Anesth 2000;14:454–456.

[12] Auckland LM, Lambert SJ, Cummin P. Cardiac myosin light and heavy chain isotypes in tetralogy of Fallot. Cardiovasc Res 1986;20:828–836.

[13] Di Donato RM, Fujii AM, Jonas RA, Castaneda AR. Age-dependent ventricular response to pressure overload. Considerations for the arterial switch operation. J Thorac Cardiovasc Surg 1992;104:713–722.

[14] Gulick J, Hewett TE, Klevitsky R, Buck SH, Moss RL, Robbins J. Transgenic remodeling of the regulatory myosin light chains in the mammalian heart. Circ Res 1997;80:655–664.

[15] Koch WJ, Milano CA, Lefkowitz RJ. Transgenic manipulation of myocardial G protein-coupled receptors and receptor kinases. Circ Res 1996;78:511–516.

[16] Kiriazis H, Kranias EG. Genetically engineered models with alterations in cardiac membrane calcium-handling proteins. Annu Rev Physiol 2000;62:321–351.

[17] Mee RBB. Severe right ventricular failure after Mustard or Senning operation. Two stage repair: PA banding and switch. J Thorac Cardiovasc Surg 1986;92:385–390.

Appendix A. Conference discussion

Dr J. Fragata (*Lisbon, Portugal*): I would like you to comment, if possible, a bit more on the size of the shunt you are using. I did it myself six times and we lost one patient because maybe the banding was too tight. But I think the shunt size I always chose tended to be more on the small size, not on the big size, for instance, 4 or 5 mm, because I think that's important, especially if the patients have not been submitted to a Rashkind procedure. Would you mind commenting on that, please?

Dr Lacour-Gayet: I agree that you should be on the short size, 3.5. The banding, the increase of the wall stress and the overload are an enormous stimuli to the left ventricle. If, in addition, there is a volume stimulus created by too large a shunt, especially if the ASD is not very large, it is too much for the left ventricle. So I think that we could tolerate some cyanosis and put probably a small size shunt. I agree with you.

Dr Fragata: So you would use a 3.5 or a 4?

Dr Lacour-Gayet: Well, it depends on the age.

Dr Fragata: The point I wanted to make is that if you are using a big size shunt and in the presence of a restrictive ASD, maybe you would be much more in trouble because of difficult mixing, as you know.

Dr Lacour-Gayet: I don't totally share this point, because a simple transposition surviving after 3 months with no PDA and no ASD, is difficult to imagine. So there is probably always an ASD, sometimes not very big. But the use of a Rashkind has not been on practice as it is difficult to do at 3 months of age; furthermore, if there is an ASD and a PDA, the patient can probably be switchable.

Dr M. Elliott (*London, UK*): I would like to correct something that you said just now, that I was advocating ECMO. That's not true. We have done approximately 40 patients over the age of 3 weeks up to a maximum age of 84 days with a single/stage switch, without measuring LV mass. Although, we may have a selected subset, in that group ECMO has only been used in two patients. Now, to me the philosophical question is, is it advantageous to retrain a ventricle in the presence of cyanosis or is it advantageous to retrain a ventricle after you have done the correction in the presence of normoxia? We don't know the answer. But I think it's premature to say that an LV mass of 35 is correct because you haven't tested that hypothesis. This has just been something you've chosen retrospectively. Also 'eyeballing' of the banana size of the ventricle is relatively subjective. We could argue that we ought to be able to organize some kind of multicenter prospective trial. I would like to ask you what you think about the idea of retraining in the presence of oxygen and retraining in the absence of oxygen?

Dr Lacour-Gayet: Well, I understand your point with oxygen. First, transposition is a cyanotic disease, and when you do a banding plus a shunt, you have a saturation that is in the range of 75, 80, which is acceptable. Now, the ECMO is a technique that is more and more in control, and recently we have been quite satisfied with the results of ECMO in our center. Nevertheless, each time we bring a patient back to ICU with an ECMO, the intensivists are usually furious. So we believe this is more a rescue method than a technique that should be developed routinely. I agree with your approach, and I know that there are groups in the United States and in Europe that are doing this technique as well, but if you look at the cost and if you look at the number of nurses and perfusionists required, it's a lot more expensive than to do a banding that you can leave in place just for 4 or 5 days.

Dr Elliott: This is less than 10% of the patients, and you had almost the same number requiring ECMO in your late series.

Dr Lacour-Gayet: Well, again, I agree with you that ECMO is a good procedure. To consider that retraining should be done through ECMO is a way to do it; but so far we have considered that it is a very aggressive method that should be, again, probably used as a rescue more than anything else.

Dr M. Hazekamp (*Leiden, The Netherlands*): Our experience with 10 patients is very similar to yours, with important hemodynamic instability after the first operation.

I have two questions. What happened to the patient who went on to have a Senning operation? The second question is, why did you have to retrain the left ventricle in two patients who were under 2 weeks of age?

Dr Lacour-Gayet: The patient with the Senning did well. The Senning, as you know, they do well for the majority of the patients.

Now, why did we have to retrain patients less than 2 weeks of age? When the LV mass is calculated and the aspect of the ventricle is poor, it's a bit scary. I am talking about mass less than 20 g. It makes sense to have a short retraining before switch. In fact these two patients were small ones, less than 2.5 kg; in an ECMO at 2.1 kg, you are not really sure that you can have a good result. So I believe that the security is behind retraining borderline patients.

Dr A. Corno (*Lausanne, Switzerland*): I have two questions. Your oldest patient was 8 months of age. We have seen patients coming at 12, 18, and 24 months of age with TGA/intact ventricular septum, no PDA. Would you consider a Senning or Mustard procedure in these cases or not?

Dr Lacour-Gayet: We only included in this article retrained left ventricles in a surviving native population of D transposition; but we have retrained patients well above 8 months. Now, again, I think that the cardiologists have to tell us whether the quality of the myocardium is the same. There are recent papers that expressed some concerns regarding the quality of the contractile protein spatial organization in these patients.

Dr Corno: Even at this age we do a left ventricular retraining, but we associate the creation or the enlargement of the ASD. So we do, like you, a shunt and loose banding, but with always a short period of cardiopulmonary bypass to enlarge the ASD because they are very desaturated when they come, like 50%, 60% oxygen saturation.