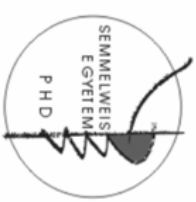


# Innovative Techniques in Cardiac Surgery Using the Apex of the Heart

PhD Thesis

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The principal investigator of the studies evaluating the most valuable innovative methods described by this thesis

is

**Tamas Szil-Torok MD, PhD.**

The international part of these studies is running under his supervision,  
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## 1. Introduction

The relationship between the apex of the heart and cardiac surgery is controversial. There are only a few entities of surgically curable diseases of the heart that directly involve the apex itself. The apex, however, should still be considered a significant part of the heart. Historically there were two major obstacles on the way of surgeons to treat heart diseases. On one hand manipulation involving the internal structures while the heart has to maintain the circulation and on the other hand the avoidance of the deteriorating effect of artificial circulatory support were problematic for decades. The apex was one of the first regions of the heart that gave hand to the surgeons to solve these problems. The most successful, therefore the safest and most cost effective localization for inserting a left ventricular decompression cannula is the apex. It was even more important in the early era of open heart surgery, when special cannulas were not available, and intraoperative monitoring devices for detecting left ventricular dilation, were not in use either. Thousands of patients suffering from rheumatic mitral stenosis were treated successfully with closed commissurotomy also in the early era of open heart surgery, when the most appropriate instrument, the Tubbs dilator was positioned in the mitral orifice by insertion into the left ventricle through the apex of the heart. It provided treatment option for larger group of patients, because the higher cost of operations with heart-lung machine reduced significantly the number of valve surgeres applying the open procedure. Innovative techniques using the apex have been continuously developing in every field of cardiac surgery.

## 2. Aims

Our aims were to evaluate the leading role of the apex in the revolutionary innovations of cardiac surgery in the recent years.

1. Assessment of the role of the apex in Off Pump Coronary Artery Bypass (OPCAB) operations.
2. Safe connection is necessary between the heart-lung machine and the main arteries of the body for surgical treatment of acute proximal aortic dissection. The establishment of the safe connection is impeded by the dissection itself. We evaluated the role of apical cannulation in establishing cardiopulmonary bypass in regard to the perfusion of vital organs.

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3. Surgical treatment of heart failure with long term mechanical circulatory support providing whole body perfusion is one of the recent revolutionary techniques. Our aim was to apply this method in Hungary too. To achieve our goal we also evaluated the role of apical cannula implantation in safe and effective long term mechanical circulatory support.
4. Another increasingly important treatment of the heart failure is the Cardiac Resynchronization Therapy (CRT). We developed a fundamentally new approach for alternative LV lead implantation for CRT. Our prominent aim was to evaluate the effect of our new method in the ratio of responders to CRT.

### 3. Methods

1. After the initial experience with OPCAB operations (1995), we "re-engineered" our team work in the theatre (1999) and performed this type of operation for isolated coronary artery bypass in all relevant cases. We examined the feasibility of the method with performing elective revascularization in the first 27 consecutive patients. We conducted an extended study to evaluate the early and mid-term results in the first 209 patients operated after September 1999. We compared the results with patient groups that were operated with heart-lung machine on the basis of indication of non-elective postoperative revascularization. These control groups were set up from patients of two different cardiac surgery centers of Hungary. We conducted further studies to evaluate the role of apical suction device in hemodynamically better heart positioning for OPCAB. We evaluated its effect in patients with severe multivessel coronary artery disease. We compared the results achieved when for surgical treatment at least one over 9 mm length distal anastomosis was necessary with results when only regular length distals were necessary. Our other study was the comparison between the blood levels of CK, CK-MB and cardiac troponins after coronary bypass operations without and with heart-lung machine in 315 and 196 patients, respectively after 2003.
2. We studied the possible causes of malperfusion in vital organs during operations to treat acute proximal aortic dissection. We evaluated the risks of unintended connection between the heart-lung machine and the main arteries of the body during artificial perfusion. The native and artificial perfusions in acute proximal

3. aortic dissection are only identical when the arterial cannula inserted through the apex in the left ventricle and led through the aortic valve into the proximal ascending aorta. We also evaluated the efficacy of this type of cannulation in our clinical practice.
3. We studied the long term mechanical circulatory support to treat heart failure and the possibilities to perform this treatment in Hungary too. Long term mechanical circulatory support has two significant risks of complications: One is a device related infection, the other is a thromboembolic/hemorrhaging complication. We evaluated these possible complications in relation with apical cannula implantation. We assessed the role of long term mechanical circulatory support in pediatric heart transplantation with regard to donor heart shortages and progression behavior of heart failure in childhood.
4. After we developed a fundamentally new method for CRT (2007), we evaluated the feasibility of our method by collecting data during and after the first 10 operation. We assessed the risks of other alternatives of CRT and other possibilities for endocardial pacing of the left ventricular lateral wall in comparison with our method. We compared the results achieved with surgical epicardial lead implantations and the results with our transapical endocardial lead implantations in 12 and 10 patients respectively. Heart failure patients with some type of congenital heart diseases and some type of surgical corrections of their congenital heart disease are not suitable for standard CRT with coronary sinus lead implantation. We assessed the characteristic features of this patient group and the exceptional possibility for CRT of these patients with our method.

### 4. Results

1. The results were excellent with the elective revascularization in the first 27 consecutive OPCAB patients. Baseline clinical characteristics in the study group of 209 patients did not show significant differences from any other coronary artery disease patient groups. According to the early and mid-term results the graft patency in off-pump cases is at least equivalent to the graft patency in on-pump coronary bypass operations. There was no need for revascularization in the study group in the average follow-up time of 12.4 months. In the control groups (1275 and 347 patients) the incidences of revascularization were 4.3% and 4.6%

- in the average 3.5 and 8.7 months follow-up period. OPCAB enhanced with the apical suction device provided this excellent result even if we operated an increasing number of patients suffered from more severe multivessel coronary artery disease. This severe multivessel coronary artery disease was proved in 35% of our patients (n=67), when at least one over 9 mm length distal atherosclerosis was needed at the operation. CK-MB releases after the operations did not differ between patients with long and regular sized distals (average 28.3 U/l vs. 30.1 U/l). Distribution of 67 study-group and 142 control group patients in NYHA functional classes at the end of the follow-up period (average 12.4 months) was not different either (NYHA I: 75% vs. 77%, NYHA II: 20% vs. 19%, NYHA III: 5% vs. 4%). In our other study OPCAB was clearly superior for avoiding myocardial injury when we compared the postoperative blood samples of 315 study-group and 196 control patients (CK: p<0.001, CK-MB: p<0.001, troponin I: p=0.003, and troponin T: p<0.001).
2. Artificial perfusion without transapical arterial cannulation would have been insufficient in one third of patients in our clinical practice of surgical treatment of acute proximal aortic dissection. If only other type of cannulation had been applied, it would not have provided tolerable perfusion for vital organs without serious damage right from the beginning of the operations. We performed successful artificial perfusion for cooling with apical cannulation in three cases.
  3. Hungarian pediatric heart transplantation program took a successful start in Goltsegen György National Institute of Cardiology in 2007. Progression of heart failure is more rapid in children than in adults. The shortage of donor hearts in pediatric transplantation program is more significant than in adult transplantation program. To keep the pediatric transplantation program successful the successful application of long term mechanical circulatory support is absolutely necessary. We had to build up all the supporting facilities of this type of treatment in our institution. To prevent device related infections we had to learn better infection control, especially in dressing the cannula ports. Against the other significantly dangerous risk, the thromboembolic/hemorrhaging complication we provided bedside thrombolastograph and aggregometer first time together for supporting long term mechanical circulatory support therapy in Hungary. As a result of our planned training and preliminary work between 29 September

and 1 November 2008 we performed the first successful bridge-to-transplant therapy with a Berlin Heart EXCOR® Bi-ventricular assist device. One of the most important parts of the applied system is the LV apical cannula. The pumps and tubes with all transparent plastic outer surfaces are paracorporeal in this system. For appropriate anticoagulation management we also performed visual pump-control regularly.

4. We have been able to perform effective CRT in patients with failed coronary sinus route for left ventricular pacing since 2007. Our method provides this result by inserting the endocardial pacing lead through the apex into the left ventricular cavity using minithoracotomy approach. The endocardial fixation can be performed at the optimal place for CRT. Endocardial left ventricular pacing provides better hemodynamic and less proarrhythmic effects than epicardial pacing with either coronary sinus or surgically implanted epicardial leads. Transapical endocardial leads do not pass the valves in the left heart, which has a beneficial effect to avoid device related valvular endocarditis. We were the first to apply this technique with success in the world. We already implanted leads with our method in 10 patients since the first implantation. All of the patients responded favorably in the average 7.2 months follow-up period. We compared these results with the results of 12 patients who underwent surgical epicardial leads implantations. All patients were responders in both groups. As previously reported, chronic pacing and sensing parameters with endocardial leads in the right side of the heart are generally better than these parameters with epicardial leads. We observed these beneficial effects of endocardial pacing within the left ventricle as well. Based on our experiences we developed a multicenter study protocol for CRT with transapical left ventricular leads in heart failure patients with congenital heart disease or surgical correction of their congenital heart disease, because in these conditions the coronary sinus route to implant left ventricular leads is not available.

## 5. Main Conclusions

1. According to our results we would say that OPCAB is the most cost-effective method today for revascularization in two- and three-vessel CAD and in patients with one-vessel disease who are not

2. Transapical cannula insertion through the left ventricle and the aortic valve into the proximal ascending aorta is the only life-saving arterial cannulation for emergency operations in acute proximal aortic dissection in a significant proportion of patients.
3. Safe application of long term mechanical circulatory support is indispensable for a successful pediatric heart transplantation program. We performed a modality of this treatment with success in Hungary, too. One of the most important parts of the applied Berlin Heart® which can provide whole body perfusion is the left ventricular apical cannula.
4. CRT is the increasingly important treatment of heart failure. We performed the first transapical left ventricular endocardial lead implantation in the world. Our alternative method allows significantly more patients to be responders of CRT, because it is less invasive, safer and provides endocardial pacing.

### List of publication

#### Publications connected to the PhD

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15. **Kassai I, Földesi C, Székely A, Szili-Török T.** Alternative method for cardiac resynchronization: transapical lead implantation. *Ann Thorac Surg.* 2009; 87: 650-2

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## Összefoglalás

A szívcsücsös számos vonatkozásban kiemelt jelentőségű a szívsebészeti tevékenység szempontjából, annak ellenére, hogy ömágárikán mutat beavatkozást indokoló patológiai elváltozást. A műtéti technikák forradalmi újításában a szívcsücsös szerepe a kezdetektől napjainkig nélkülözhetetlen. Szívbeteggek milliói köszönhetik eredményes kezelésüket az így kialakított módszereknek. Az esetek egy részében már ismert eljárás vált biztonságosabbá: a szívcsücsi dekompressziós balkamrai szűrés, a szívcsücsi artériás kamatlátás akut aortadiszzekcióban, és végül, de nem utolsósorban az OPCAB műtéténél a szívcsücsön tapadó pozicionáló eszköz sorolható ide. A szívcsücs segítséggel olyan módszerek is megjelentek, melyekre egyébként nem lett volna lehetőség, ezek a következők: az aortabílyentűi betegségének alternatív kezelése, a tartós balkamrai keringéstámogató eszközök beültetése, és az alternatív balkamrai endokardialis ingerítés a reszinkronizációs kezelés részeként.

Jelen doktori tézisek szerzője kiemelkedő tapasztalatokkal rendelkezik ezen a területen, a felsorolt módszerek közül csak keleti nem alkalmazott korábban, közülük az egyik még nincs a hazai gyakorlatban. A koszorúerek betegségének sebészti kezelése tekintetében folytatott tudományos kutatói, fejlesztői tevékenységének eredményeként OPCAB műtétet a szerző közölte elsőként Magyarországon (*Kassai I. et al. 1995*).  
Alternative method for coronary revascularization: surgery without cardiopulmonary bypass. Card Hung. 24(3): 14-6). Hasonló felkészülést követően elsőként alkalmazta a szívcsücsi kamatlátást akut proximális aortadiszzekció műtétéhez. Az első sikeres „bridge-to-transplant” tartós mechanikus keringéstámogató Magyarországon a Gótszegén György Országos Kardiológiai Intézetben történt, ahol a szerző ennek a programnak a megszított koordinátora. Az alkalmazott Berlin Heart® mindkét szívfélét támogató műsziv egyike legfontosabb része a balkamrai csücsi részhez csatlakoztatott kanál. Szoros együttműködésben kardiológus kollégáival a szerző kifejlesztette és a világon elsőként, és sikerrel alkalmazta a reszinkronizációs kezeléshez alapvetően új alternatívaként a balkamrai elektroda endokardialis rögzítését a szívcsücsön keresztül történő bevezetéssel (*Kassai I. et al. 2008*, New method for cardiac

resynchronization therapy: transapical endocardial lead implantation for left ventricular free wall pacing. Europace 10(7): 882-3, és *Kassai I. et al. 2009*, Alternative method for cardiac resynchronization: transapical lead implantation. Ann Thorac Surg. 87: 650-2). A szívelégtelenség eszközös kezelésének a reszinkronizáció egyre növekvő fontosságú formája, az erre a kezelésre responder betegek számát ez az új módszer szignifikánsan képes növelni.

A disszertációban a jobbi a szívsebészeti területen végzett tudományos munkájával bizonyítja a folyamatos innováció és az így megjelent új módszerek alkalmazásának jelentőségét, mely ékiesen cáfolja a manapság gyakran felhúklkano véleményeket a szakterület hanyatlásáról.

## Summary

The apex is one of the most useful parts of the heart in surgical treatment although it does not often show pathological changes requiring surgical intervention. It has played an indispensable role in the appearance of the truly innovative surgical techniques and keeps it at present as well. These methods mean recovery and convalescence for millions of people with heart diseases. Some of the methods made the already existing techniques safer like the LV vent or the LV arterial cannula in dissections and last but not least the apical suction devices in OPCAB surgery. Some others have served as basis for new kinds of treatments which could have never appeared without the use of the cardiac apex. These are the alternative treatment options for aortic valve disease, the preferable implantation method in left ventricle assist device therapy, and the transapical lead implantation for completing CRT systems.

The author of this thesis is well-trained and skilled in this field, only two of the above mentioned procedures are without his personal experience, one of them not being presented in Hungary at all. The OPCAB method without as well as – after its availability – with the apical suction device (**Kassai I, et al. 1995**. Alternative method for coronary revascularization: surgery without cardiopulmonary bypass. *Card Hung* 24(3), 14-6), and the arterial cannula through the LV apex for surgical treatment of acute proximal aortic dissection have been applied for the first time in Hungary by him, based on and proved by his detailed scientific research about surgery for coronary artery disease and aortic dissection. The first successful bridge-to-transplant long-term mechanical circulatory support in Hungary belongs to the team of the Gótszegén Hungarian Institute of Cardiology where he is in charge of this project. One of the most important parts of the applied Berlin Heart® BiVad system is the LV apical cannula. With close cooperation of his cardiologist colleagues, the author developed a fundamentally new approach for alternative LV lead implantation for CRT, and applied it with success first in the world (**Kassai I, et al. 2008**. New method for cardiac resynchronization therapy: transapical endocardial lead implantation for left ventricular free wall pacing. *Europace*. 10(7): 882-3, and **Kassai I, et al. 2009**. Alternative

method for cardiac resynchronization: transapical lead implantation. *Ann Thorac Surg*. 87: 650-2). This method allows significantly more patients to be responders of this increasingly important treatment of heart failure.

The scientific cardiac surgical works of the author detailed in this thesis prove the importance of the permanent requirement and implementation for innovative techniques in cardiac surgery despite the nowadays so frequent negative opinions about the general nightfall of this field of medicine.



### Acknowledgement

I would like to dedicate my thesis to my professors, **Ervin Szentes** – in secondary school, **Aldia Arway** and **Gyula Kerkovits** – during my postgraduate education. They have also been my ideals in the field of biological and medical sciences with their implacable precision and consistency accompanied by their humanity.

I am grateful for my professors and teachers **Zoltán Szabó**, **László Lukács**, and **András Szatmari** not only for their help to improve my medical knowledge but also for their indispensable pieces of advice during my carrier.

Dear **Tamas Szil-Török** and **Peter Andréka**, I am grateful that both of you have been willing to be my mentors and consultants when working on my thesis. Working with you has been a great pleasure and your scientific knowledge and friendship are enormously inspiring.

Working with my young colleagues, **András Vigh**, **Éva Bodi**, **Orsolya Friedrich**, my trainees, and **Csilla Zsidó**, a registered scrub-nurse at work, and helping to extend their scientific knowledge on about issues identical with parts of my thesis was the greatest motivation.

This thesis has been written in English and for language revision I would like to say grateful thanks to **Tamas Heil**, my head and friend at Moravia IT.

I would like to thank the **GYÖRGY GOTTSEGEN FUNDATION** for the permanent support of my medical scientific work.

I would also like to say thank you to my close and distant relatives here. Most of the time I must have seemed to be a rather fanatic and useless acquaintance who is almost incapable for anything but hospital work. Without their understanding and supportive backing, I could have never achieved anything valuable in my profession.