<u>PhD doctorial dissertation</u>

TOTAL ARTERIAL REVASCULARISATION WITH RADIAL ARTERIY GRAFTS

Zoltán Galajda MD.

Supervisor: Árpád Péterffy MD. PhD

UNIVERSITY OF DEBRECEN, MEDICAL AND HEALTH SCIENCE CENTER
DEPARTMENT OF CARDIAC SURGERY
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I. Introduction

I/1. A brief history of the coronary bypass

The first attempts for direct surgical treatment of coronary illnesses go back to the middle of the 1940-ies, when in Montreal Vineberg commenced application of the internal mammary artery for this purpose. The artery was led into the heart muscle, but the later clinical results did not certify the expectations. In the Murray experiments in 1954, anastomosis was created between the internal mammary artery (IMA) and the coronary arteries. By this in actual fact he opened the era of operations carried out on coronary arteries.

Thanks to the work of Sones and Shirey at the beginning of the 60-ies it became possible to fill and display the coronary arteries, with this laying the foundations for diagnostical conditions for coronary surgery. In the mean time the bypasses carried out on coronary arteries came into existence. Coronary bypass with the patient's own saphenous vein was first established by Sabiston in 1962, while at the end of the 60-ies Favaloro and Johnson developed and made clinical practise, the application of vein grafts for the purpose of coronary bypasses. Coronary bypass with the IMA was performed first by Goetz in 1960, but the utilisation of arterial grafts was spread and became widely known as a result of the work by Green and colleagues. In the first decades of coronary surgery, mainly bypasses produced with venous grafts were applied with preference, having regard to the relatively rapidity and simplicity of the method. Bypasses with IMA were carried out in only a few centres, and at the beginning of the 80-ies those publications appeared which proved that the bypasses formed using the mammary remained open in significantly better manner than venous grafts, in both the short and long-term. In the following decades the use of internal mammary artery supplemented by venous grafts was applied in a routine manner. Having regard to the fact that after 8-10 years artery sclerotic deformations appear in the venous grafts, thus it appeared necessary to look for newer arterial grafts, from which more favourable, long-term results could be expected. For this reason the use of the radial artery, the gastroepiploic artery and the epigastric inferior artery was commenced. The clinical application was preceded by numerous histological and

physiological studies. Combined utilisation of the radial artery and the mammary internal provided the opportunity for total arterial revascularization (TAR).

In our institute we commenced using the radial artery for coronary bypasses in 1998. In this way the opportunity was provided for carrying out complete arterial revascularization, using the internal mammary artery from one or two sides and the radial artery from one or two sides.

The routines use of the radial artery for the purpose of total revascularization, and development of a new operating procedure, obtaining the radial graft with a less invasive method, were set as objectives.

In the following I should like to outline an analysis on the internal mammary artery, as ideal arterial graft, and the radial artery, as auxiliary arterial graft for coronary bypass operations.

I/2 The internal mammary artery (internal thoracic,IMA)

By virtue of its anatomical proximity and biological character, the IMA is the most suitable graft for coronary bypass, and is used today in a routine manner. Its particular revascularizational capacity was already discovered by Vineberg's experimental and clinical researches (1967), as a result of which the IMA was applied as a myocardium-implant, accompanied by omentum covering. Other, earlier observations also indicate that the IMA implants establish an ample connection with the coronary branches, and significantly increase the ischaemic heart muscle supply.

Introduction of the open heart operations established the opportunity for using the IMA as a direct graft for coronary bypass. The experience gained in the decades past since then proved that from among all the grafts, the internal mammary is the ideal graft. In Hungary Péterffy and colleagues were the first to apply the internal mammary for coronary bypass (1989).

I/3 The Radial Artery (AR)

Among the systematic arteries, by virtue of both size and structural characteristics, the AR is prospectively the most suitable graft, which was first used for coronary bypass by Carpentier in 1973. At that time the method did not prove to be

successful, because a large part of the grafts dried out within a short period, and therefore the initiator himself, and others reached the conclusion that the radial artery was unsuitable for this purpose.

Almost twenty years passed before the AR again became the centre of interest, and following lengthy examinations, precisely Carpentier's followers brought to light the causes of the failure.

Acar and colleagues describe in detail the AR macro and microscopic morphology from material originating from corpses and re-operated patients, and in 1993 they published the experience gained from operations on 158 patients. Their surprisingly good results indicate that with strict observation of certain operation regulations, the radial artery is a biological material which can be utilised at least as successfully as the widely used and favoured saphenous grafts.

II. Patients and methods

Between July 1998. and December 2000. at the Department of Cardiac Surgery, Medical and Health Science Center Debrecen radial artery grafts were utilised on 517 patients (415 males and 102 females). The average age of the patients was 56.2 years of age (min. 32, max. 79).

In Debrecen radial graft harvesting was carried out first by the initiator of this thesis, applying a traditional method.

Individual parameters of the pre-operative, intraoperative and post operative periods were processed statistically. The "SPSS for WINDOWS 9.0" statistical programme package was used for mathematical statistical processing of the data. The applied tests were the following:

- Student t-test

- One-Way ANOVA

- $?^2$-test (Chi-square test)

- Linear Regression and Pearson's Correlation Coefficients

Follow up of the patients was carried out, and is still being carried out at present, with questionnaires and control examinations.

Up to 1st September 2001., assessment questionnaires were sent to 365 patients, of which 301 patients replied (82%). The questions listed in the questionnaires can be put into three big data groups:

1. Complications in the forearm, after removal of the radial.

2. The patient's quality of life.

3. Complaints under load (L), from L1 (under minimal load), up to L4 (no complaints).

- Character of daily physical loading (work-W), from W1 (does not carry out physical work), up to W3 (does sports, carries out physical work).

On the patients reporting for control examination, echocardiography, loading ECG test, and dependent on the patient's consent, control catheterization were carried out.

II/1 The method of obtaining radial grafts

In the following I shall cover in detail the surgical technique of radial artery harvesting. The obtaining of radial grafts is possible by the traditional method or by a less invasive method. Independent of the method, it is obligatory to examine the forearm circulation before the operation. The Allen test[*] proved to be insufficient in itself, therefore today's standpoint is that a pre-operative Doppler examination is recommended before removal of the radial artery.

In the case of ulnar artery hypoplasia or agenesia, or possible "arcus palmaris interruptus", removal of the radial artery could lead to acute ischaemia of the upper limb.

The Allen test can give a misleading result, for example if the dorsal superficial branch of the radial artery or the median artery are present as anatomical variants.

These arteries can supply the palmar arch even if the radial artery is clamped down. Therefore the initiators recommend a modified „Allen" test (Allen-LEC test).

II/2 Radial artery harvesting by the traditional method

One of both of the patient's forearms are positioned in supination, such that the angle between the upper limb and the body axis is 70°. If only harvesting of the left radial is planned, harvesting of the left internal mammary and the left radial artery is carried out at the same time.

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[*] The time for palm recolouring after physical loading (with compressed radial and ulnar artery) such that the radial artery remains clamped meanwhile the ulnar is released.

In the case of using radial arteries from both sides, the right side is carried out with a harmonic scalpel, thus shortening the time required for obtaining the grafts. In a suitable alignment the left internal mammary and the right sided radial artery can be harvested at the same time.

The traditional technique applies a longitudinal forearm incision, directly above the run of the radial artery. The incision is slightly curved, in an S shape, following the medial edge of the brachioradial muscle.

Two main requirements of the operation must be satisfied: it must be atraumatic with respect to the radial artery, and the forearm's blood supply, innervation and function should not be impaired.

II/3 The obtaining of radial grafts by a less invasive method

The possible obtaining of radial by a less invasive method, is through two 2 cm long transverse incisions. The operation takes place under endoscopic inspection, using special instruments. World literature gives accounts of very few cases up to date, emphasising the excellent aesthetic results of the method. At the same time, the use of an endoscope makes obtaining of the graft more difficult, requires more personnel, increases the time necessary for graft obtaining, and probably the risk of traumatic effect on the graft is greater.

With the method worked out by us, the minimal invasive operation can be carried out without an endoscope, under observation with the naked eye. The basic principle of this is that with the help of a spiral instrument, the radial artery remains protected in the centre of the spiral, then the collateral branches are cut through with a harmonic scalpel.

Instruments necessary for the operation: a special exposer provided with a light source, a fascial lifter, spiral artery collectors of various sizes, harmonic scalpel with 14 cm scalpel.

The instruments and the operating technique have been presented with demonstration operations, because the method aroused the interest of a few foreign medical instrument manufacturing companies. The novelty of the method applied by us consists

of the fact that such instruments are used together, which ensure protection for the graft, thus the use of an endoscope is not necessary, and the operation can be carried out within a short time, even under conducted anaesthesia.

III. Results

Between July 1998. and December 2000. radial artery grafts were utilised on 517 patients for coronary operations.

Breakdown by sex of the patients: 415 males (80.3%), 102 females (19.7%).

The average age of the patients was 56.2 years of age.

The patients were divided into three age groups. It can be seen from the following table that 54.5% of the patients came within the "51-65" age group.

Breakdown of the patients by age group

Age group (years)	N (number of patients	%
<50	151	29.2
51-65	282	**54,5**
>65	84	16,2
In total	517	100,0

Pre-operation data

	N	Minimum	Maximum	Average	SD±
Weight	429	45	125	81,7	12,7
Age (years)	517	32	79	56,2	8,8
Time passed between infarct and operation	215	0,0	204	26,1	39,0
Left chamber function (EF)%	461	20,0	70,0	51,3	9,4

Other pre-operation data		
	N	*%*
Diabetes	147	28,4
Hypertonia	182	35,2
Varicosity of lower limbs	10	1,9

Our aim was to carry out tomplete arterial revascularization, using one or two sided IMA grafts and one or two sided radial artery grafts.

Using internal mammary grafts and radial artery grafts, we performed total arterial revascularization in 87% of patients.

The early mortality was 1.9%.

The average of peripheral anastomoses (carried out on the coronary) was 3.2, while the average of central anastomoses (carried out on the aorta) was 1.6.

	N	Minimum	Maximum	Average	SD±
Peripheral anastomosis	517	1	6	3,2	1,0
Central anastomosis	517	1	4	1,6	0,6

The utilisation of internal mammary was 88.7%, in the following breakdown:

- LIMA on 419 patients (81%)

- RIMA on 12 patients (2.3%)

- LIMA and RIMA on 28 patients (5.4%)

Radial grafts were utilised in the following manner:

- LRA on 301 patients (58.2%)

- RRA on 16 patients (3.0%)

- Two side AR on 200 patients (38.6%).

Intraoperative data:

Extracorporal circulation

Time (minutes)	N	Minimum	Maximum	Average	SD±
Aorta clamping	452	12	250	65,5	30,6
ECC	452	41	400	107,4	45,7

Early re-operation due to complications

	N (patients	%
There were none	498	96,5
Resternotomia (bleeding)	9	1,7
Extra CAGB	2	0,3
Laparotomia	3	0,5
Mediastinitis, osteomyelitis	5	0,9
Femoral artery occlusion	1	0,1
In total	517	100

The patients' average artificial breathing time was 15.0 hours, the average time spent on ICU was 45.9 hours.

The average blood quantity discharge through the drains was 1063.9 ml. 57.4% of this (on average) the patients received back by autotransfusion (ATF).

In 8 cases (1.5%) a balloon pump (IABP) was used in the immediate post operative period, on 4 patients due to perioperative infarction (0.7%), while on 4 patients due to reduced left ventricle function.

There was no perioperative infarction due to radial graft dysfunction.

The average nursing period for patients was 11.3 days.

The causes of death: reduced left ventricle function or perioperative infarction (8 cases), acute lower limb ischaemia and serious arteriopathia (1 case) and acute ischaemic failure of the intestinal tract (1 case).

III/1. Patient follow up (processing of questionnaire data) - 301 patients

Later death occurred with 10 patients (1.9%), and on the basis of data collected from the questionnaires, with 9 patients the death was of cardiac origin, while one patient died of laryngeal cancer.

The patients were called back for control examination one year after the operation.

Prior to this data sheets were sent out by post, by the processing of which, we assessed the post operation hand or forearm complications, the patients' life quality, and physical load bearing tolerance. On the occasion of the control examination we checked the authenticity of complaints shown in the data sheets, then supplemented the examination with a load tolerance ECG examination.

Dependent on their consent, the patients were recalled for a control coronary angiography, for which permission was given by the University Ethical Committee (Nr. 956/2001).

The data sheets of 301 patients were processed statistically.

Forearm or hand paraesthesia in the superficial radial nerve area, occurred in 12.6%. These complaints ceased during 1-20 months (on average within 6.3 months).

Temporary neurological complications occurred in only 4%, after the less invasive operations.

In contrast to other authors, we did not find a significant connection between the diabetes and the neurological complications.

IV. Discussion

If we look back over the history of coronary surgery, and analyse the results against the experience of today, the application of internal mammary artery for coronary bypass, can be said to be revolutionary. At present also, this artery plays the role of ideal graft.

Because of its restricted length, the mammary artery is not sufficient on its own for carrying out all of the bypasses, therefore the use of other, auxiliary arterial grafts seemed to be necessary. Thus following the „rehabilitation" of the radial artery, it became a publicly acknowledged and utilised auxiliary graft after the years of the

nineties. In Hungary Lukács and colleagues were the first to use the radial artery for coronary bypass.

The operating technique for obtaining the radial graft, is still under development at present. It is still not clarified as to under what conditions should the graft be stored until its utilisation, whether antispastic treatment is needed or not, and how does the coronary vessel's discharge path influence the graft remaining open. With my work, I have attempted to contribute to the solving of these questions.

Between 1988 - 2000 we used the radial artery for coronary bypass on 517 patients. Our objective was, by this means to carry out complete arterial revascularization. The experience up to now certifies that the radial grafts, as opposed to venous grafts, remain traversable for a longer period.

Long-term results can only be achieved with good quality grafts. The graft quality is determined by the structural and functional characteristics of the artery - which can be influenced only partially with the operation - and by the applied operating technique. This must be considerate in relation to not only the graft, but also to the part of the body from where the artery was removed.

Surveys are being carried out world wide, among both the patients and the surgeons, to discover how big is the „demand" for the less invasive method. In an interesting manner, when questioned before the operation, with very many patients the forearm's aesthetical view point only plays a secondary part.

On the basis of our assessments however, the neurological complications are unambiguously fewer after the less invasive technique. This is a significant point of view for every patient. According to literary data the proportion of neurological complications after removal of the radial artery can reach 30.1%. With our patients these complications occurred in 12.6 %, while in only 4% after application of the less invasive method. The instruments used for this method are not uniform in a world relation, and only a few centres apply the less invasive technique's endoscopic variation.

The procedure worked out and applied by us makes it possible to obtain the grafts without an endoscope, atraumatically, in a short time and with few neurological complications. Its application however requires sufficient experience, besides detailed

anatomical knowledge. In our institute the less invasive method has only been carried out by one surgeon up to now (the author of the thesis).

On the basis of our experience, the radial is an ideal graft for carrying out the sequential anastomosis. The thickness and flexibility of the artery wall prevents torsion of the graft between two peripheral anastomoses. Fewer central anastomoses are needed for the sequentially sutured grafts (sutured to the aorta), and a larger discharge path can be ensured for the graft.

In the case of using one side radial artery, we always utilised the non-dominant forearm. Post operative forearm haematoma or bleeding only occurred in 4 cases (0.7%). Sometimes the surgeons are unaccountably cautious of using the Redon drain, although at the same time unobserved carpus haematoma can be a serious source of neurological complications.

With elderly patients the radial artery could also be arteriosclerotically effected. In the future a Doppler test carried out regularly before the operation could pick out those cases where the radial artery is of unsuitable quality or even unusable.

The average postoperative blood discharged through the chest drains was 1060 ml. This can be compensated for well with autotransfusion.

The postoperative creatinine level was not in connection with the autotransfusion quantity, thus from this point of view there is no contra recommendation to the ATF.

The use of the balloon pump proved to be fortunate in the case of reduced left ventricle function. In such cases the balloon must be put in place during the operation or already before the operation.

With the internal mammary artery supplemented by one or two side radial arteries, an opportunity is given for carrying out total arterial revascularization. We carried out total arterial revascularization on 87% of our patients, with good post operative results and low mortality (1.9%). This does not mean that it is expedient to endeavour to carry out complete arterial revascularization on every patient. A radial artery graft sutured to a reduced discharge coronary path, will probably become closed in a short time, and we deprive the patient of a valuable reserve arterial graft.

The patency of the grafts are checked with post operative control coronary angiography. The results up to now have been encouraging, however the assessment of

these is only possible with a greater number of cases. Angiographical forecasts indicate that the prognosis is encouraging for radial artery grafts sutured to coronary vessels with a good discharge path and proximal significant restriction. At the same time, the radial artery grafts obtained by us using the less invasive technique, illustrate well operating radial grafts even two years after the operation.

This thesis is based on the following publications:

1. **Z. Galajda** and Á. Péterffy. Minimally Invasive Harvesting of the Radial Artery as a Coronary Artery Bypass Graft. Ann Thorac Surg, 2001, 72: 291-3 **IF: 2,022**

2. **Z. Galajda,** E. Jagamos, T. Maros, Á. Péterffy: Radial artery grafts: surgical anatomy and harvesting techniques. J Cardiovasc Surg (In Press).

3. **Z. Galajda,** I. Szentkirályi, Á. Péterffy: Neurologic complications after radial artery harvesting: J Thorac Cardiovasc Surg 2002 Jan;123(1):194-5 **IF: 3,057**

4. **Galajda Zoltán,** Péterffy Árpád. Az artéria radialis nyerése endoszkópos eszközzel: új mûtéti eljárás a koszorúér-sebészetben. (Orv. Hetil.2000. 141, 38: 2069-2116). In hungarian

5. **Z. Galajda,** I. Mikó, J. Hallay, T. Maros, Á. Péterffy, I. Furka. Why the internal mammary artery is an ideal graft for myocardial revascularisation? Acta Chirurgica Hungarica, 36, 1-4, pp 92-94 (1997)

6. Péterffy Á., **Galajda Z.,** Horváth A. A koszorúér betegség korszerû sebészi kezelése (Lege Artis Medicinae, 2000, 10: 875-880) In Hungarian

7. Péterffy Árpád, **Galajda Zoltán.** Az artéria mammaria interna a koszorúér áthidalásokat vezérelve (Cardiologia Hungarica 2000; 4: 269)

8. Péterffy Á., **Galajda Z.,** Horváth A. A koszorúerek teljes artériás revaszkularizációja (TAR) iszkémiás szívbetegségben. A Magyar Kardiológusok Társasága védnökségével 2001. 79. ISBN 963 9070 475