Diplomarbeit

Evaluation of alternative grafts in coronary artery bypass surgery
Evaluation of long-term results by Cardiac CT

eingereicht von

Nadine Cornelia Sandra Meinelt

Geb.Dat.: 23.11.1986

zur Erlangung des akademischen Grades

Doktor(in) der gesamten Heilkunde

(Dr. med. univ.)

an der

Medizinischen Universität Graz

ausgeführt am

Institut / Klinik für Herzchirurgie

unter der Anleitung von

ao univ. Prof. Dr. Ameli Yates

Dr. Katharina Meszaros

Ort, Datum Graz, 25.01.2013

Eidesstattliche Erklärung

Ich erkläre ehrenwörtlich, dass ich die vorliegende Arbeit selbstständig und ohne fremde Hilfe verfasst habe, andere als die angegebenen Quellen nicht verwendet habe und die den benutzten Quellen wörtlich oder inhaltlich entnommenen Stellen als solche kenntlich gemacht habe.

Graz, am 25.01.2013 *Unterschrift*

Danksagungen

Mein Dank geht an alle, die mir bei der Erstellung der Diplomarbeit geholfen haben.

Alle meine lieben Freunde, die während der gesamten Studienzeit immer für mich da waren: Ich danke euch herzlichst, ohne eure Unterstützung wäre vieles viel schwerer und einiges unmöglich gewesen.

Der größte Dank geht an meine Eltern.

Liebe Mama, lieber Papa; Vielen vielen Dank, dass ihr mich Zeit meines Lebens immer unterstützt und bekräftigt habt, meinen Traum zu verwirklichen. Danke, dass ihr jede einzelne Sekunde an mich geglaubt habt, danke, dass ihr immer für mich da wart und danke, dass ihr mich nie im Stich gelassen habt, wenn etwas mal nicht ganz rund gelaufen ist. Ohne euch wäre ich nie so weit gekommen.

Danke.

Zusammenfassung

Hintergrund: Alternatives Graftmaterial (Vena cephalica (CV), Vena saphena parva (SSV), biocompound-gestützte Venengrafts) wird eingesetzt, wenn konventionelles Material nicht zur Verfügung steht. Wegen mangelnder Daten konnte die Wahl des Grafts bisher nur unzureichend auf wissenschaftliche Daten gestützt werden. Ziel diese Studie war die Evaluierung alternativen Graftmaterials in einer Fallserie, das an unserer Institution zum Einsatz kam.

***Methoden*:** Aus insgesamt 1570 Patienten (Bypassoperation zwischen 2008 und 2011 an der Klinik für Herzchirurgie am Universitätsklinikum Graz) wurden 36 Patienten mit alternativen Grafts herausgesucht, um mittels Cardiac computed tomography (CT) die Langzeitoffenheit der alternativen Grafts zu evaluieren. 24 von 36 Patienten wurden primär ausgeschlossen, 12 Patienten wurden eingeladen und schließlich sieben von ihnen untersucht. Drei Patienten gaben ihr Einverständnis, Ergebnisse aus Coronarangiographien (unabhängig von der Studie durchgeführt) zu verwenden, was eine Gesamtteilnehmerzahl von zehn Patienten mit 20 alternativen Grafts (6 CV Grafts, 6 SSV Grafts, 8 biocompound-gestützte GSV Grafts) ergab.

Ergebnisse: Zwei SSV- und zwei CV- Grafts konnten postoperativ nicht endgültig zugeordnet werden. Von den verbliebenen vier CV-Grafts waren alle vier verschlossen (Offenheit 0%), von den vier SSV-Grafts waren drei offen und ein Graft verschlossen (Offenheit 75%). Drei von acht biocompound-gestützten GSV-Grafts waren offen, was eine Offenheitsrate von 37,5% ergibt.

***Diskussion*:** Wegen der geringen Zahl an Studienteilnehmern ist die Aussagekraft der Studie limitiert. Um eine Aussage über die Verwendung von alternativen Graftmaterial treffen zu können, wurden unsere Ergebnisse mit anderen Studien mit demselben Thema verglichen.

Conclusio: Alternatives Graftmaterial zeigt sehr unterschiedliche, aber im Vergleich zu konventionellem, besonders arteriellem, Graftmaterial, immer schlechtere Offenheitsraten und sollte deshalb nur verwendet werden, wenn ansonsten kein anderes (arterielles) Material zur Verfügung steht.

Abstract

Background: Alternative graft material (cephalic vein (CV), small saphenous vein (SSV), biocompound-supported vein graft) comes to use when conventional material isn´t available. Due to lack of information the choice of grafts has so far not been supported by scientific data. The aim of this study was to evaluate alternative graft material in a case series, that came to use at our institution.

Methods: From altogether 1570 patients (coronary artery bypass graft (CABG) between 2008 and 2011 at the Department of Cardiac Surgery at the university hospital in Graz) 36 patients who received alternative conduits were selected to evaluate the long-term patency of the alternative conduits by Cardiac computed tomography (CT). 24 of the 36 were primarily excluded, 12 were invited and finally seven of them examined. Three patients consented in using results from coronary angiography (conducted independently from the study), which made a total of ten patients with 20 alternative conduits (six CV conduits, six SSV conduits, eight biocompound-supported GSV conduits).

Results: Two SSV conduits and two CV conduits could postoperatively not be assigned definitely. From the remaining four CV grafts zero were patent and all four occluded (patency rate 0%), from the four SSV grafts three remained patent and one was occluded (75% patency rate). Three of eight biocompound-supported GSV grafts remained patent and five were occluded, which equals a patency rate of 37,5%.

Discussion: Due to a small number of participants our study is not representative for long-term patency rates of alternative conduits. To make a statement about the usability of alternative graft material, our results were compared to other studies thematizing the same subject.

***Conclusion*:** Alternative graft material shows very variable outcome but compared to conventional bypass grafts, especially arterial conduits, evermore poorer results in terms of long-term patency. Therefore it should only be used for coronary artery bypass grafts when any other (arterial) graft material is unavailable or unsuitable.

Table of Content

Abbreviations

LITA	Left Internal Thoracic Artery
RITA	Right Internal Thoracic Artery
RA	Radial Artery
GSV	Great Saphenous Vein
SSV	Small Saphenous Vein
CV	Cephalic Vein
CAD	Coronary Artery Disease
CABG	Coronary Artery Bypass Graft
ESC	European Society of Cardiology
PCI	Percutaneous Coronary Intervention
LAD	Left Anterior Descending Artery
2VD	Two Vessel Disease
3VD	Three Vessel Disease
LV	Left Ventricle
1VD	One Vessel Disease
OMT	Optimal Medical Therapy
CHF	Congestive Heart Failure
FFR	Fractional Flow Reserve
ACS	Acute Coronary Syndrome
STEMI	ST-Elevated Myocardial Infarction
NSTEMI	Non-ST-Elevated Myocardial Infarction
BV	Basilic Vein
CT	Computer Tomography
ECG	Electrocardiography

CAB	Coronary Artery Bypass
GFR	Glomerular Filtration Rate
RCA	Right Coronary Artery
CX	Circumflex Artery
LM	Left Main Coronary artery
DX	Diagonal Branch
OM	Obtuse Marginal Artery
PDA	Posterior Descending Artery
PAD	Peripheral Artery Disease

List of Figures

List of Tables

1. Introduction

1.1. Indications for alternative graft material

In aortocoronary bypass surgery arterial graft material (left internal thoracic artery, LITA, right internal thoracic artery, RITA, and radial artery, RA) and venous grafts (the great saphenous vein (GSV)) are standardly used for coronary bypasses (1-4).

In case of massive varicosis, after varicose vein surgery or thrombosis /sclerosis of the GSV and , if not enough arterial grafts are available, the surgeon has to switch strategy to use alternative graft material. In some patients with severe generalized atherosclerosis, arterial material was not suitable as bypass conduit of sufficient quality (1-4)

As an alternative to the conventional and arterial grafts either the short saphenous vein (SSV) (5-13) or the cephalic vein (CV) (14-22) can be used as a graft to create the aortocoronary bypasses.

In most cases, the indication for use of alternative graft material is clear before surgery. A pronounced varicosis or atherosclerosis is detected in the preoperative physical examination and the medical history. Nevertheless in some patients a varicosis of the extracted material primary presents intraoperatively during the leakage test (usually by purging the material with saline solution or heparinized blood) owing to the resulting higher pressure. In these cases, either one of the two possible alternative veins is harvested additionally or the already extracted material is processed with the biocompound technique (23-25).

1.2. Coronary artery bypass graft surgery

1.2.1. Indication for surgical revascularization

The ideal therapeutic strategy for patients with coronary artery disease (CAD) depends on several factors. Indications for coronary artery bypass graft surgery

(CABG) are presented in Tab. 1 according to the European Society of Cardiology (ESC) guidelines. (2,26)

1.2.1.1. ESC-Guidelines

The ESC guidelines 2010 for myocardial revascularization in general (percutaneous coronary intervention (PCI) and CABG) are based on the results of different studies. These studies showed, depending on the severity of the disease, a significant improvement in both symptoms and prognosis in patients with CAD who underwent either surgical or interventional revascularization compared with those receiving drug therapy. Table 1 shows the results and derived indications for patients with stable angina or silent ischemia. (2,26)

	Subset of CAD by anatomy	**Class**	**Level**
For Prognosis	Left main > 50% *	I	A
	Any proximal LAD > 50% *	I	A
	2VD or 3VD with impaired LV function *	I	B
	Proven large area of ischemia (>10% LV) *	I	B
	Single remaining patent vessel >50% stenosis *	I	C
	1VD without proximal LAD and without >10% LV*	III	A
For Symptoms	Any stenosis >50% with limiting angina or angina equivalent, unresponsive to OMT	I	A
	Dyspnea/CHF and >10% LV ischemia/viability supplied by >50% stenotic artery	IIa	B
	No limiting symptoms with OMT	III	C

*** with documented ischemia or Fractional Flow Reserve (FFR) <0.80 for angiographic diameter stenosis 50-90%**

Table 1: Indications for myocardial revascularization in stabile angina or silent ischemia (26)

For patients with need of an emergency intervention like in acute coronary syndrome (ACS), ST-elevation myocardial infarction (STEMI) or non-ST-elevation myocardial infarction (NSTEMI), these criteria are also valid. In addition to those in emergency patients the impossibility of an PCI, PCI failure or a one vessel disease (1VD) with pronounced infarction area with significant limitation of myocardial function applies as an indication for immediate surgical revascularization, as long as the infarct area is not yet necrotic (within the first four to six hours after the acute event). (26)

1.3. The different graft types used for CABG

Choosing the right material is crucial for quality and long-term patency of coronary artery bypasses. The main conduits are described below.

1.3.1. Conventional bypass grafts

The conduits which are standardly used for CABG are referred to as conventional bypass grafts. These are arterial grafts like the left or right internal thoracic artery (LITA or RITA), radial artery (RA) and the great saphenous vein (GSV). (1,2,4,27)

Conventional bypass grafts	
Arterial Grafts	• Left or right Internal thoracic artery (LITA or RITA) • Radial artery (RA)
Venous Grafts	• Great saphenous vein (GSV)

Table 2: Conventional bypass grafts (1)

1.3.1.1. Arterial bypass grafts

Arterial grafts show better long-term patency than venous grafts, wherefore LITA and RITA depict the gold standard in bypass conduits. In some cases the RA is also used as a graft; other arterial conduits such as the right or left gastroepiploic artery were used, but their harvesting is associated with a higher morbidity and mortality due to the necessary laparotomy. (1,2,4,27)

1.3.1.1.1. Internal thoracic arteries

The left internal thoracic artery (LITA) represents the gold standard for surgical revascularization on the anterior wall in connecting it to the left anterior descending artery (LAD). Due to its close anatomic relation and the ideal anastomotic angle, the LITA is routinely anastomized to the LAD as in-situ graft; only in cases of very distal stenosis the LITA has to be connected to the ascending aorta, when it risks to be too short as in-sit-graft; however, the long-term results of an in-situ-LITA graft are better than of free graft with proximal aortic anastomosis. (28-33)

The right internal thoracic artery (RITA) can be used as in-situ graft or free graft for revascularization of the branches of the right or circumflex coronary system. Compared to LITA grafts the RITA shows slightly decreased but still satisfactory patency rates. (13,34-37)

1.3.1.1.2. Radial artery

The radial artery seems to have all the qualities required for a coronary artery bypass conduit (adequate caliber, absence of atherosclerotic disease, and being designed to withstand arterial pressure), it is relatively easy to harvest.

Radial artery harvesting is contra-indicated in patients with positive Allen Test; in these patients, the anastomosis between the superficial and deep palmar arch - which is supplied by the ulnar artery - is not sufficient and harvesting the radial artery would pose a risk of arm ischemia.

The radial artery shows the best long-term patency when grafted to occluded or highly stenosed coronary arteries with good run-off, in case of borderline stenosis with significant concurrent flow of the native coronary vessel or poor run-off, the radial artery tends to be spastic and is therefore associated with a low long-term patency.(1,2,38-48)

1.3.1.2. Great saphenous vein

In addition to the left internal thoracic artery the great saphenous vein (GSV) is the most commonly used conduit in aortocoronary bypass surgery. The GSV is easy to harvest, available in sufficient length, also in case of reoperations, and can be connected easily to all coronary targets. Above all in cases of emergency revascularization with concomitant hemodynamic instability, the patient does not support LITA harvesting, so the operative strategy has to be changedto fast connection to extracorporal circulation with simultaneous harvesting of GSV, which can be performed very fast.

Saphenous vein grafts are at risk to develop early and late graft failure. Early graft failure is mostly caused by bypass graft thrombosis, late graft failure is developing due to intimal hyperplasia, above all at proximal and distal anastomotic site. (1,2,28,30,33,34,49)

1.3.2. Alternative bypass grafts

In patients who, due to certain preconditions (generalized atherosclerosis, poor Allen Test, varicosis or state after varicose vein surgery) the conventional grafts cannot be used, the surgeon must switch the operative strategy in choosing alternative conduits. These are primarily the small saphenous vein (SSV), upper extremity veins (mostly the cephalic vein, CV) or biocompound-supported vein grafts, as seen in the table below. (1-3,27,50)

Alternative grafts
• Small saphenous vein • Cephalic vein • Biocompound-supported vein

Table 3: Alternative graft material

The various options for alternative conduits are briefly described in the following text.

1.3.2.1. Short saphenous vein

The short saphenous vein (SSV) is sometimes used as alternative conduit when the GSV is not available or unsuitable. The SSV exhibits dome disadvantages, such as shorter length, a normally smaller diameter, and a relatively time-demanding harvesting caused by its anatomical course at the backside of the lower leg. The leg has to be rotated in the hip joint and rotated outside in the knee joint, a second person is normally necessary to hold the leg in this position during harvesting, because the patient lies in dorsal position. The wall of the SSV is usually weaker than the one of the GSV, so it has to be supported in some cases by use of a biocompound external nitinol mesh. (5-13)

1.3.2.2. Cephalic vein

When neither the GSV or the SSV is available or suitable as a conduit, an alternative for venous conduits can be a vein of the upper extremity, primarily the cephalic vein (CV), occasionally the basilic vein (BV) is used. Though the CV is of adequate length even for multiple bypasses, it is rather thin walled and prone to kinking, twisting and aneurysmatical dilatation after placement.

In the Department of Cardiac Surgery in Graz CV grafts are therefore supported by a biocompound mesh to stabilize its walls, to protect it of the higher arterial pressure. Exceptions are arm vein conduits with a high quality and stable vessel wall, which is intraoperatively evaluated by the operating surgeon. (14-22)

1.3.2.3. Biocompound-supported venous grafts

In cases of available but varicose GSV grafts, the wall can be supported by a biocompound external mesh (see Figure 1). In this technique, the vein is surrounded from the outside with a flexible metal mesh that in its structure is similar to a stent. The mesh is fixed with fibrin glue to the surface of the vein from the outside to strengthen its wall and to even out the irregularities. So, the vein can withstand the higher arterial pressure and thrombosis is largely prevented due to the correcting of the wall´s irregularities. Nevertheless, long-term patency of all these alternative graft techniques remain unclear. All published reports are limited by small patient numbers and are mostly - as it is the case in our series - small case series.(23-25).

Figure 1: Vein graft sheated with an external biocompound mesh (51)

2. Methods

2.1. Patients

The aim of this study was to follow up all patients who underwent aortocoronary bypass surgery with alternative graft material, meaning cephalic vein (CV) graft, small saphenous vein (SSV) grafts or biocompound-supported great saphenous vein (GSV) grafts, at the Department of Cardiac Surgery in Graz. The clinical examination provided us accurate information about the current clinical status of patients with special regard to dyspnea, angina pectoris, incidence of cardiovascular events since surgery, and the quality of life of patients according to a standardized scale (MacNew Questionnaire to quality of life (13)). These data will complete the follow-up.
The computer tomography (CT) provides data on the patency and the degree of stenosis of bypass grafts, with special regard to aforementioned three graft groups (= primary issue).
On one hand the patients´ bypasses should undergo a quality control by means of Cardiac CT. On the other hand the choice of a suitable graft, with lack of usable conventional graft material, should not primarily be justified by the personal expertise of the surgeon, but should be objectified by data on the long-term patency of the different alternative grafts.

2.2. Inclusion and exclusion criteria

All patients that received aortocoronary bypass grafts using alternative venous conduits, meaning either cephalic vein (CV), short saphenous vein (SSV) or a biocompound-supported great saphenous vein (GSV) conduit at the Department of Cardiac Surgery in Graz in the years between 2008 and 2011, were primarily included. In this the reason for the choice of an alternative material (varicose veins, vein stripping, too small saphenous vein or other reasons) is irrelevant. Patients who received combined valvular and aortocoronary surgery where not considered.

Exclusion criteria were the refusal to participate, claustrophobia, hyperthyroidism, known allergy to the contrast agent or reactions to the contrast agent in history, kidney failure in history or a currently existing serum creatinine above 1,3 mg/dl, as

well as a current severe disease, which makes the participation either impossible for the patient or morally or ethically not justified, and death.

Inclusion criteria	Exclusion criteria
Patients with one or more of the following alternative bypass grafts:	• Refusal to participate
• Small saphenous vein	• CT claustrophobia
• Cephalic vein	• Hyperthyroidism
• Biocompound-supported vein	• Known allergy to the contrast agent
	• Reactions in the contrast agent in history
	• Kidney failure current or in history
	• Currently elevated serum creatinine above 1.3 mg/dl
	• Severe disease or death

Table 4: Inclusion and exclusion criteria

2.3. Clinical examination

In the present study all patients with alternative graft material bypasses should be followed up with a CT-coronary angiography. To complete the data the patients were asked to answer a questionnaire about postoperative quality of life (see Annex) and persistent symptoms like dyspnea and angina pectoris. In a detailed medical history risk factors, comorbidities, and medication history were evaluated.

All patients that were eligible for the study were contacted by phone call and informed about study participation.

Prior to participation the patients were required to sign a written consent which included detailed information about the study and the process of implementation.

The patients were briefly informed about the process of the study, the extent and the study itself when they were contacted by telephone, with their appointment they would get further information as to the examination, the questionnaire, the risks and complications, but also to their own benefit they take of the examination.

First step was to set an intravenous catheter and to take a blood sample, which was tested for increased kidney values. If increased, the patient would not be able to undergo the CT coronary angiography. The results of the blood sample took about two hours, in the meantime the patient was asked to answer the questions from a standardized questionnaire on quality of life and symptoms after cardiac surgery (Mac New health related quality of life instrument, see Annex).

When the kidney values were in the normal range, the next step was the CT coronary angiography. This examination took about ten minutes and was reviewed by radiologists. The patients were informed about the contrast-induced nephropathy and were asked to see their physicians after a couple of weeks to check on their kidney.

With obtaining the laboratory results the patient was guided to the CT, where the radiological consultant explained again the process and risks of CT coronary angiography. After CT , the patient was either free to go or in dependence of the serum creatinine received an infusion to prevent contrast-induced nephropathy. The results of the examination were sent by post to their home addresses.

2.3.1. Physical examination

After execution of the written explanation of the study participation by the doctors of the Division of Cardiac Surgery and the patient´s consent to participate, a peripheral intravenous catheter for application of the CT contrast agent was placed and 10 ml of blood were taken to determine the current serum creatinine value.

In case of elevated creatinine level (above 1,3 mg/dl), the patient had to be excluded from study participation.

2.3.2.Questionnaire to quality of life and persistent symptoms after cardiac surgery

While waiting for the laboratory results the patient was asked to answer the questionnaire for postoperative quality of life (Mac New health related quality of life instrument, see Annex) with assistance of the responsible of the study. This questionnaire contains questions about typical symptoms of angina pectoris, cardiac failure (physical scale), load-bearing capacity, psychological conditions, such as depression and enjoyment of life (emotional scale). Also the questionnaire contains questions about the social environment of the patient. particularly for support in the family and assistance in dealing with the disease (social scale) (13,52).

For answering a 7-point Likert scale is used, in which 1 is the poorest and 7 is the best quality of life. The analysis is performed by determination of the average value for each patient, once for each scale (global scale, emotional, social and physical scale) (13,52).

The questionnaire is available at Annex.

2.3.3. CT coronary angiography

2.3.3.1. CT device

The study was performed using a 64-detector CT (SOMATOM Sensations Cardiac 64) with a complete rotation time of 0,33s. The device can obtain 64 slices with a routine resolution of 0,4mm by a cover of 64x0,6 mm (38,4 mm) per rotation, which means a complete examination within 10 minutes.

The volume of the contrast agent (VISIPAQUE 320) is individually adapted to each patient´s weight. It is injected through a peripheral vein catheter with an infusion speed of 5ml/s. The acquisition of the images starts, when the contrast agent reaches the ascending aorta.

The image acquisition is performed at 120kV and up to 650mA. It is synchronized with the patients ECG to reduce the radiation dose by ECG-pulsed tube current modulation to a minimum. (53)

2.3.3.2. CT coronary angiography

After an intravenous application of the contrast agent (80-100 ml VISIPAQUE 320) via the previously generated intravenous catheter the cardiac CT study was accomplished.

After creating a topogram for anatomical orientation the study was conducted according to a special study protocol for depiction of coronary arteries. This study protocol includes special settings of the used device (SOMATOM Sensations Cardiac 64).

For a good quality of the scans the patient was asked to lie quietly and to hold his breath repeatedly for ten seconds to maintain motion artifacts to a minimum. The scan was performed with ECG-rating, which means that the recording is always at exactly 65% of the RR-interval, which is the phase of the cardiac cycle, in which the coronary arteries are optimally filled with blood and can be displayed optimally. The examination itself took maximally ten minutes, further analysis was then carried out in cooperation of radiologists and cardiac surgeons.

2.4. Radiological evaluation of CT-results

In the post processing phase the coronary arteries and the bypass vessels were examined with a special software, which allows a distinction between contrast media (i.e. blood perfused vessel volume), soft plaques and calcium deposits.

The examination provided information about the patency of the bypass grafts and the degree of stenosis. Furthermore, this statement could be made for native, grafted and non-grafted coronary arteries. The main emphasis was thereby placed on the patency rate of grafts from the aforementioned three groups; conventional venous grafts and LIMA grafts were also evaluated.

Patients who showed significant stenosis and / or occlusion of bypasses were immediately transferred to cardiological treatment to evaluate the necessity and the reasonableness of interventional or surgical revascularization methods.

2.5. Data Analysis

Incorporated in the data analysis are the data which were determined with the questionnaire and the results from CT (patent or occluded bypass grafts, stenosis in bypass vessels classified according to the Fizzgibbon criteria with A > 50% stenosis (occluded) and B < 50% stenosis (patent)).

All the obtained data were investigated with a descriptive analysis.

2.6. Endpoint of the study

The primary endpoint of this study was to evaluate the long-term durability of the aforementioned three grafttypes by CT-angiography. The aim was a retrospective quality control and evaluation of the three different grafttypes coming to application at the Departement of Cardiac Surgery in Graz. The thereby achieved knowledge shall subsequently be used in the pre- and intraoperative decision-making.

3. Results

3.1. Population

From the total number of patients which received a coronary artery bypass graft (CABG) from 2008 to 2011 at the Department of Cardiac surgery at the university hospital in Graz all those who received an alternative graft material (SSV, CV or biocompound-supported vein graft) were selected. From the total number of 1570 patients these criteria only applied for 36 patients.

Given the primary exclusion criteria, which are not being available, refusal to participate, known allergy to the contrast agent, hyperthyroidism, kidney failure, other severe diseases which make a participation impossible, and death, 24 of the total of 36 patients with alternative bypass conduits were excluded from the study. Eleven of them weren´t available, four patients refused to participate, four patients had a severe disease which made it impossible for them to participate or had passed away and in five patients an elective CT with application of a contrast medium was contraindicated due to an allergy to the contrast agent (three patients total), hyperthyroidism (one patient) or kidney failure (one patient).

The remaining patients (n=12) were invited to an ambulant appointment to undergo the clinical examination and, if possible, the CT coronary angiography.

All patients took part in evaluating the postoperative quality of life by filling out the questionnaire (Mac New health related quality of life instrument, see Annex). In the clinical examination to check on secondary exclusion criteria, which means an elevated serum creatinine above 1.3 mg/dl and / or a decreased glomerular filtration rate (GFR), five of the twelve patients had to be excluded of the study.

This makes a total number of 7 patients that were examined by CT coronary angiography.

From the total number of excluded patients, three patients declared having received a coronary angiography as a follow up to their CABG and consented in the use of the results from those examinations.

Figure 1 shows an overview over the above described process.

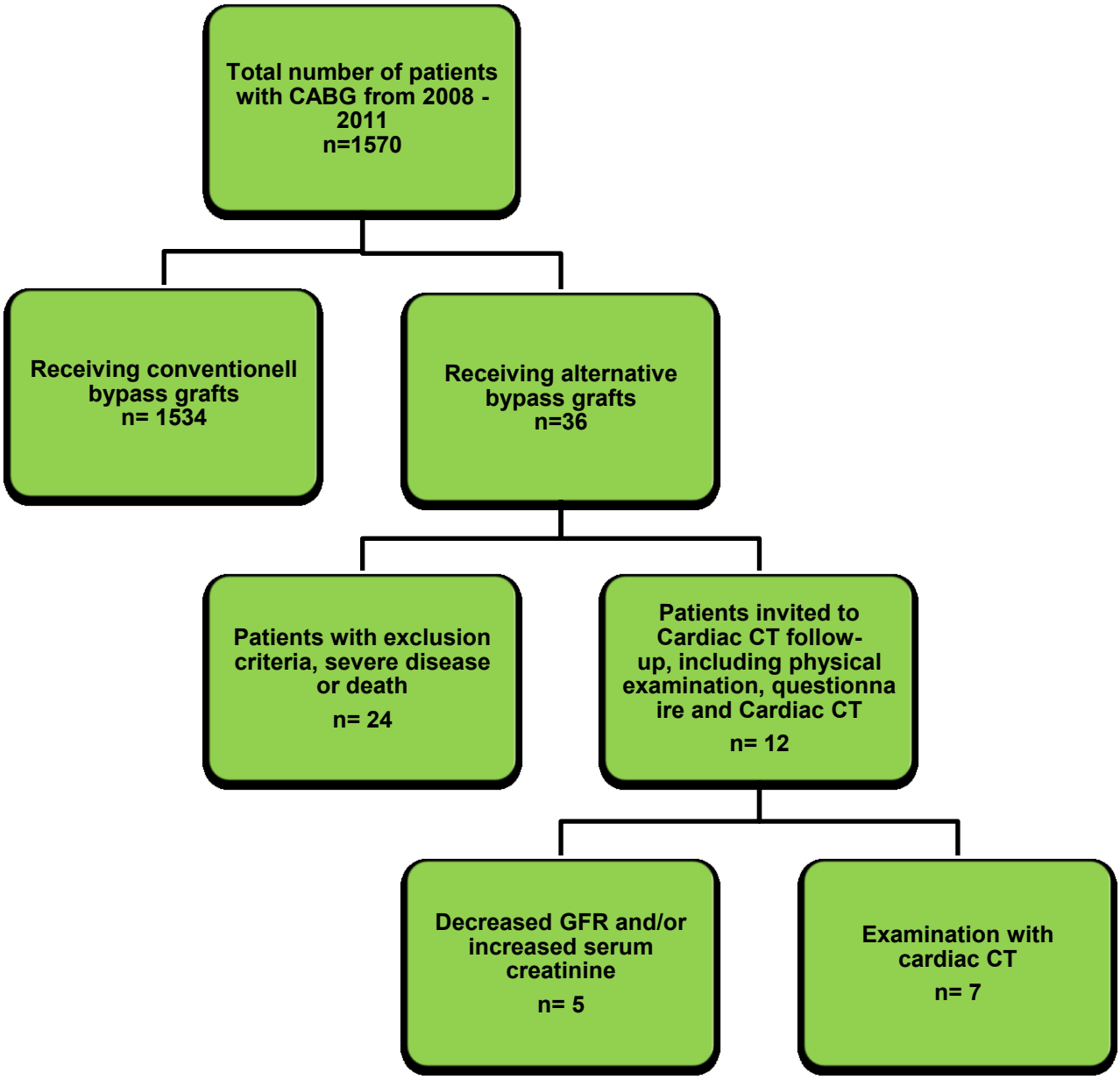

Figure 2: Process of including and excluding patients from the study

3.2. Results from CT coronary angiography

3.2.1. Patient one

3.2.1.1. Indication for alternative conduits

The patient introduced herself to the Department of Cardiac surgery in Graz in 2009 with progredient symptoms of angina pectoris and dyspnea with status post triple bypass graft in 2008 (LIMA to LAD (80% stenosis), GSV to right coronary artery (RCA) (85% stenosis) and circumflex artery (CX) (100% stenosis)). The coronary angiography showed all three bypass grafts occluded and a newly diagnosed left main- (LM)-stenosis of 70%, which set the indication for a renewed CABG.

With a bilateral varicosis a GSV conduit was not available except for small parts from the thigh, whereas only a small part from the left thigh could be harvested (left thigh GSV had been used in the primary surgery). The surgical strategy was set to harvest the left over GSV from the left thigh and in addition the CV, which appeared very thin-walled and therefore was coated with an external biocompound mesh.

The patient received a GSV conduit to LAD and a biocompound-supported CV conduit to RCA.

3.2.1.2. Results of CT coronary angiography

In the native CT scan the coronary arteries presented with three stents in LM, RCX and proximal RCA, due to artifacts the stent patency could not be evaluated.

On the contrast-enhanced scan, the LIMA-to-LAD bypass (primary surgery) appears occluded (Fitzgibbon A), the primary bypass grafts leading to RCA and RCX are not pictured (due to occlusion, Fitzgibbon A). The CV graft from the secondary surgery leading to RCA appears occluded (Fitzgibbon A). The venous bypass to the LAD appears patent, but with very small diameter (Fitzgibbon B).

Figure 2 shows the 3D-reconstruction of the cardiac CT scan, showing the GSV graft to LAD and the occluded CV bypass graft leading to the RCA. .

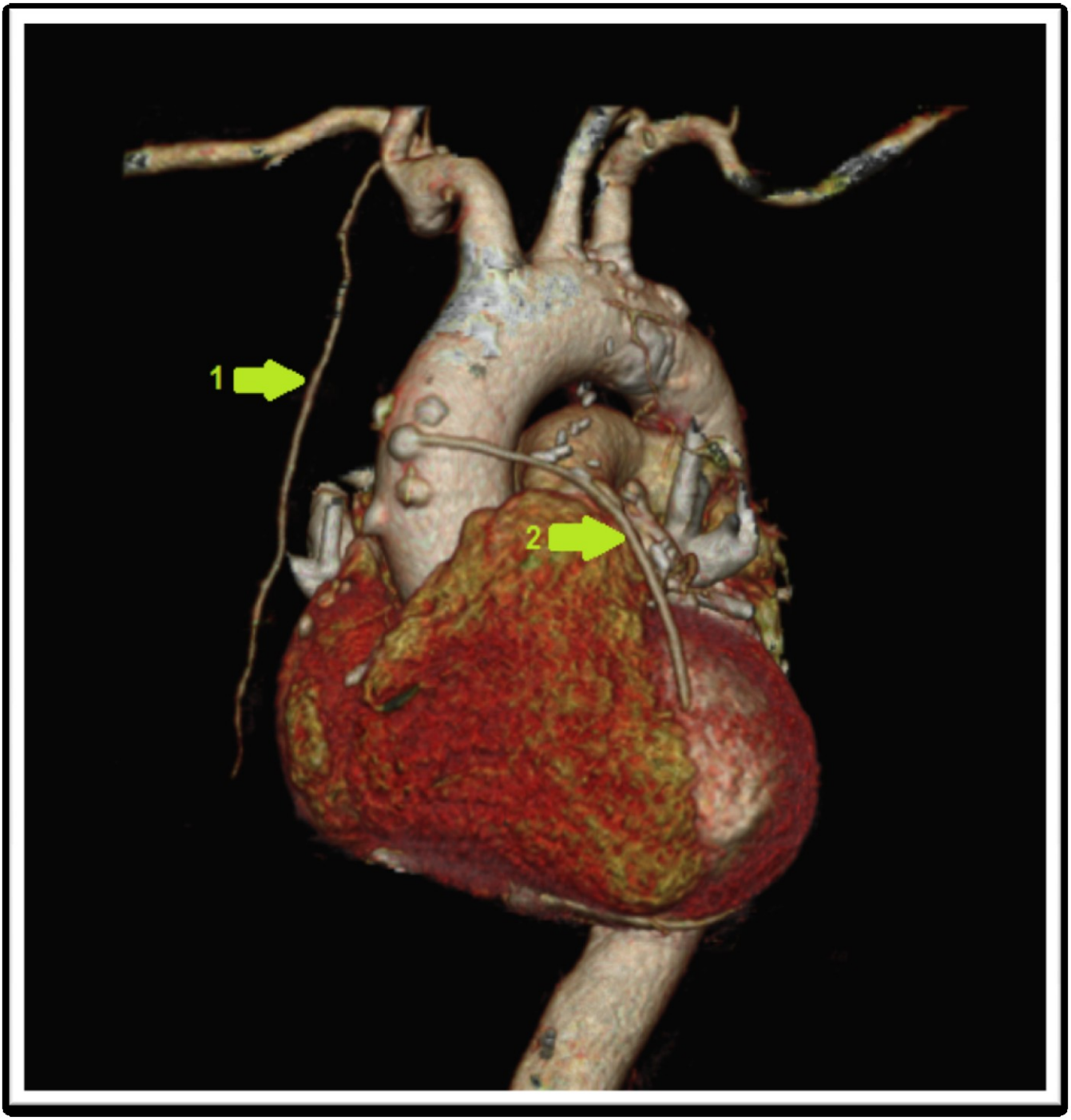

Figure 3: 3D-reconstruction (Patient 1);

1: GSV conduit leading to LAD; 2: CV graft leading to the RCA.

3.2.2. Patient two

3.2.2.1. Indication for alternative conduits

Patient two presented with acute coronary syndrome (ACS) in 2010 with progredient dyspnea and retrosternal pain with physical strain. The coronary angiography showed complete occlusion of RCA, 90% stenosis in the LM and 90% stenosis in both the LAD and CX, which clearly indicated an emergency CABG.

After bilateral varicose vein surgery GSV grafts were not available; due to generalized atherosclerosis and diabetes mellitus arterial graft material other than LITA grafts was inadvisable. The strategy therefore had been changed to harvest the SSV and in extension, as for the necessity of a triple bypass grafts, the CV.

The patient received a LIMA-to-LAD bypass and two venous bypasses to the RCA and the CX.

3.2.2.2. Results of CT coronary angiography

On the contrast-enhanced scan both the LIMA-to-LAD bypass and the venous conduit to RCA appeared patent (Fitzgibbon B), the CX bypass was not depicted and therefore considered occluded (Fitzgibbon B).

Figure 3 shows the 3D-reconstruction of the Cardiac CT scan, showing the LIMA-to LAD and the RCA bypass.

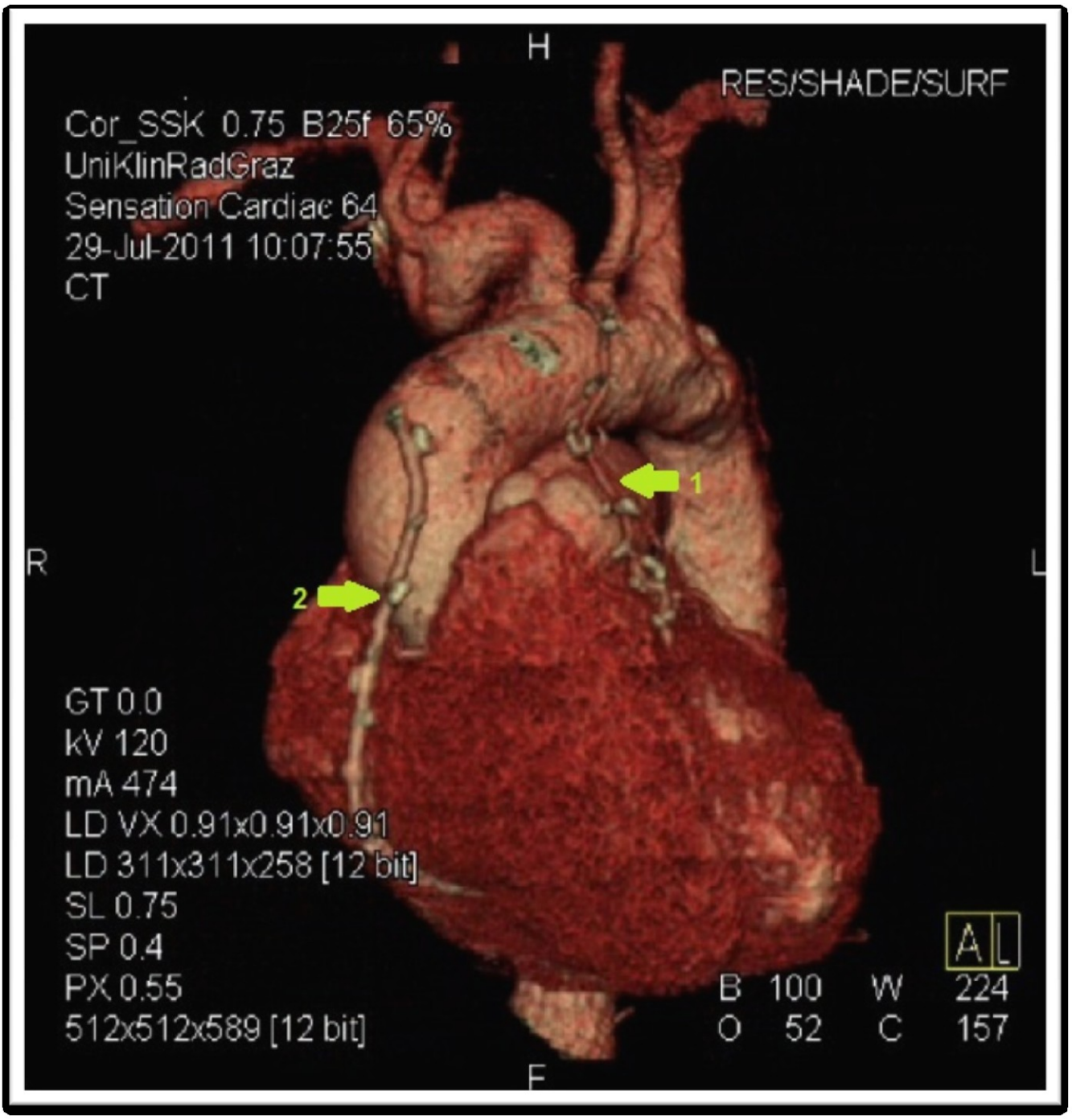

Figure 4: 3D-reconstruction (Patient 2);

1: LIMA-bypass leading to the medial LAD; 2: the venous bypass graft leading to the RCA.

3.2.3. Patient three

3.2.3.1. Indication for alternative conduits

The patient presented in 2009 with instable angina. The coronary angiography showed a 90% stenosis of the LM, 75% diagonal branch (DX)- stenosis, 60% CX-stenosis and 60% stenosis in the RCA, which clearly indicated a CABG.

A bilateral massive varicosis made both GSV and SSV grafts unsuitable, due to a generalized severe atherosclerosis arterial grafts were unavailable either, wherefore the CV was harvested. Intraoperatively the CV conduit appeared rather thin-walled and was coated with an external biocompound-mesh.

The patient received a LIMA-to-LAD bypass and a biocompound-supported CV bypass to CX.

3.2.3.2. Results of CT coronary angiography

In the contrast-enhanced scans the LIMA-to-LAD bypass appears patent (Fitzgibbon B), the biocompound-supported CV-bypass is not displayed and is therefore considered occluded (Fitzgibbon A).

Figure 4 shows the 3D reconstruction of the Cardiac CT scan, showing the LIMA-to-LAD bypass and the CV conduit leading to the CX.

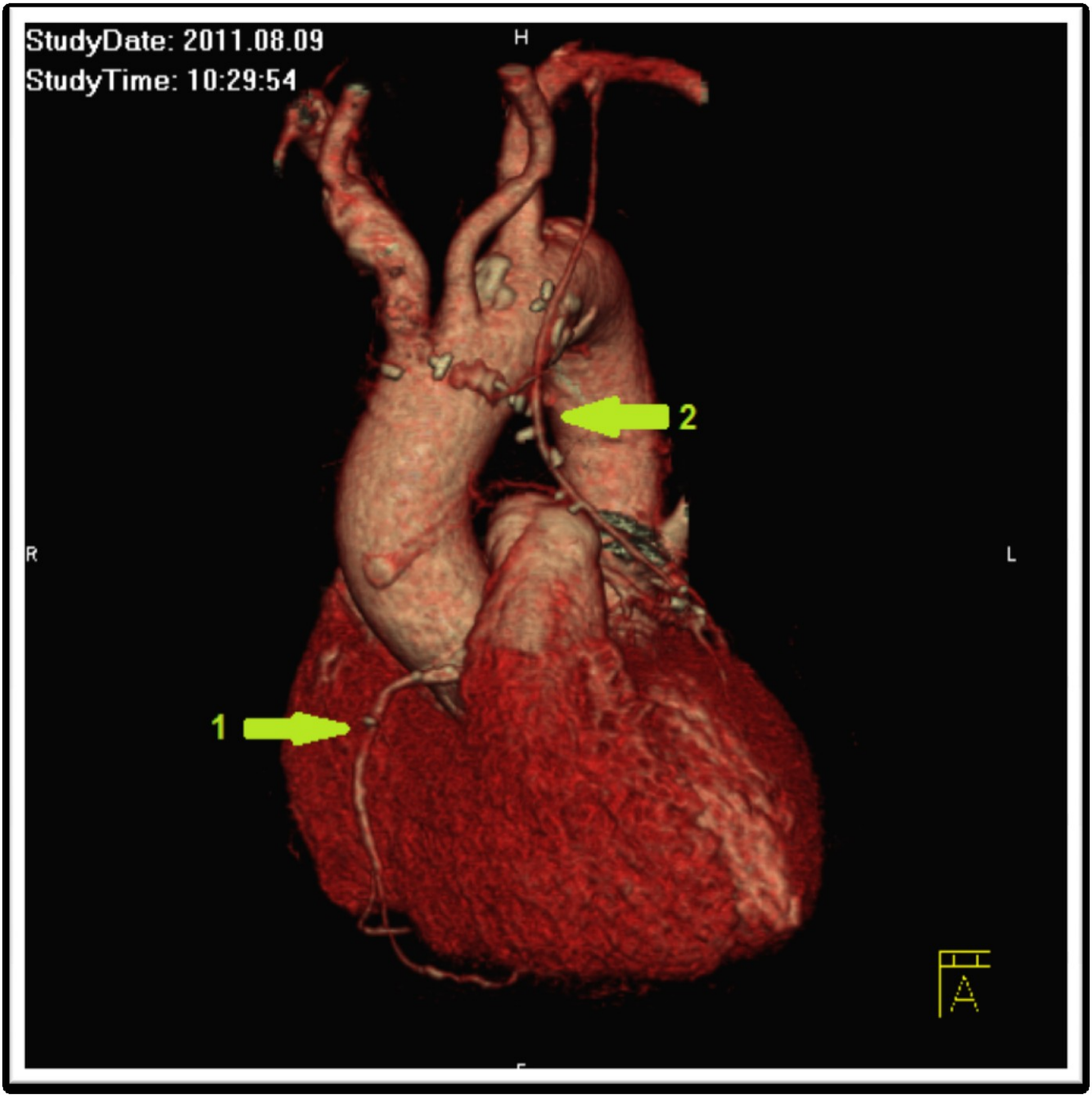

Figure 5: 3D-reconstruction (Patient 3);

1: CV conduit leading to CX; 2: LIMA-to-LAD.

3.2.4. Patient four

3.2.4.1. Indication for alternative conduits

The patient presented with progressive dyspnea and angina pectoris in 2011. The coronary angiography showed a 75% stenosis of the proximal and a complete occlusion of the medial LAD, 90% stenosis in OM, 80% stenosis in RCA and 90% stenosis of the posterior descending artery (PDA), which set the indication for CABG.

Due to massive generalized atherosclerosis with state after femoro-popliteal bypass neither arterial graft material nor a GSV conduit were available. The choice of conduits so fell, due to the necessity of multiple bypass grafts, to both the SSV and the CV.

The patient received a LIMA-to-LAD bypass and venous bypasses to the CX and ALA (Y-anastomosis) and to the RCA.

3.2.4.2. Results of CT coronary angiography

The LIMA-to-LAD bypass and the two bypass grafts to RCX and RCA appear patent but with small diameter, accordingly Fitzgibbon B.

Figure 5 shows the 3D reconstruction of the cardiac CT scan, showing all three bypass grafts.

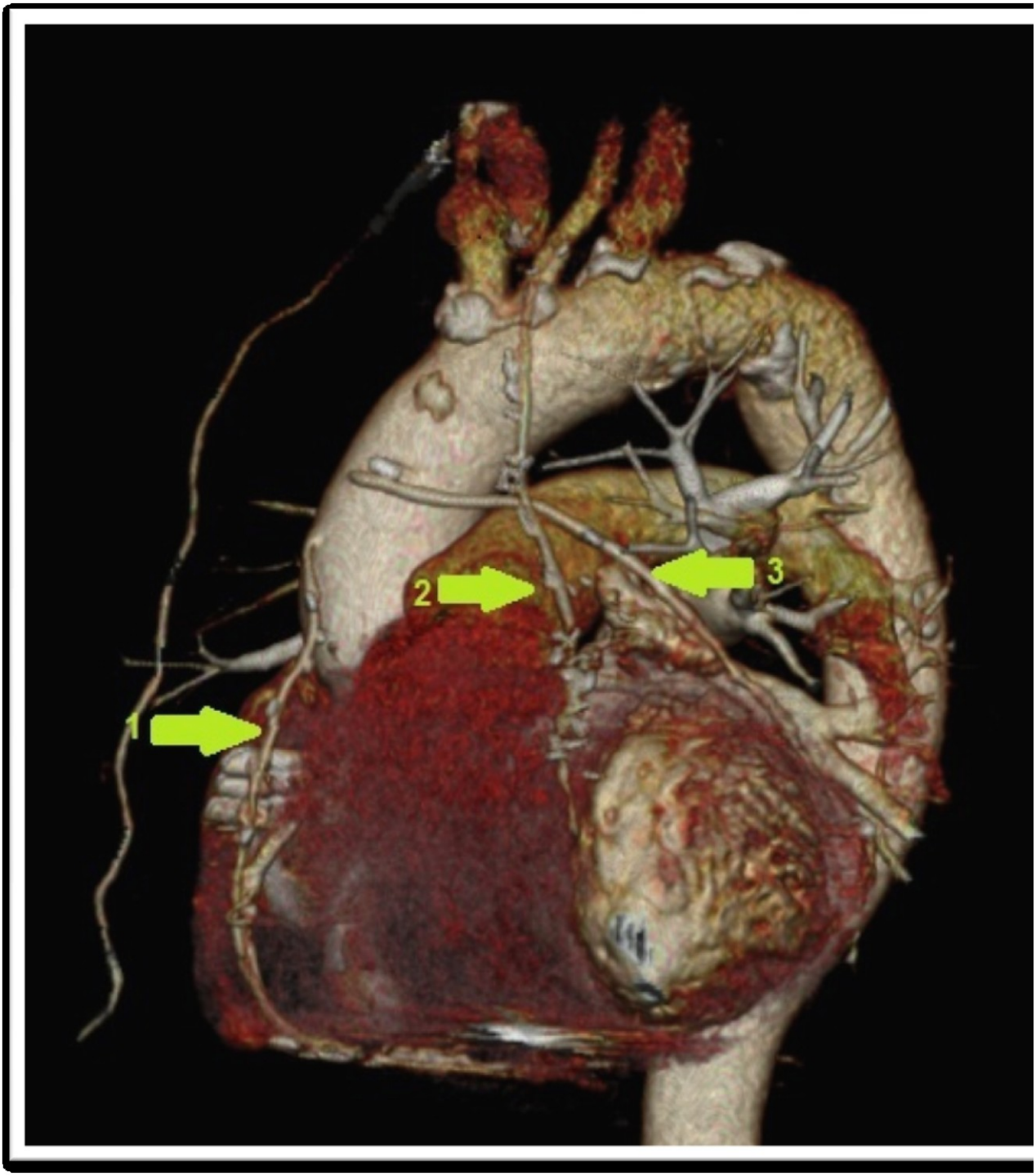

Figure 6: 3D-reconstruction (Patient 4);

1: RCA bypass graft; 2: LIMA-to-LAD bypass graft; 3: RCX bypass graft;

3.2.5. Patient five

3.2.5.1. Indication for alternative conduits

The patient primary presented with progressive dyspnea with physical strain in 2009. The coronary angiography showed significant stenosis in the LAD, the OM and the RCA.

A LIMA conduit or any other arterial graft material was inadvisable due to a massive generalized atherosclerosis with partially pronounced manifestation (ACI stenosis, aortic sclerosis, massive calcifications in every great vessel), whereas also the CV was excluded. A massive bilateral varicosis seemed to exclude GSV or SSV grafts, due to lack of alternatives the varicose GSV was harvested and coated with an external biocompound mesh.

The patient received venous biocompound-supported GSV conduits to the LAD, the OM and the RCA.

3.2.5.2. Results of CT coronary angiography

The venous bypasses leading to the LAD and the OM appear patent (Fitzgibbon B), the RCA bypass is not displayed and therefore considered occluded (Fitzgibbon A).

Figure 6 shows the 3D-reconstruction of the Cardiac CT scan with the two patent aortocoronary bypass grafts.

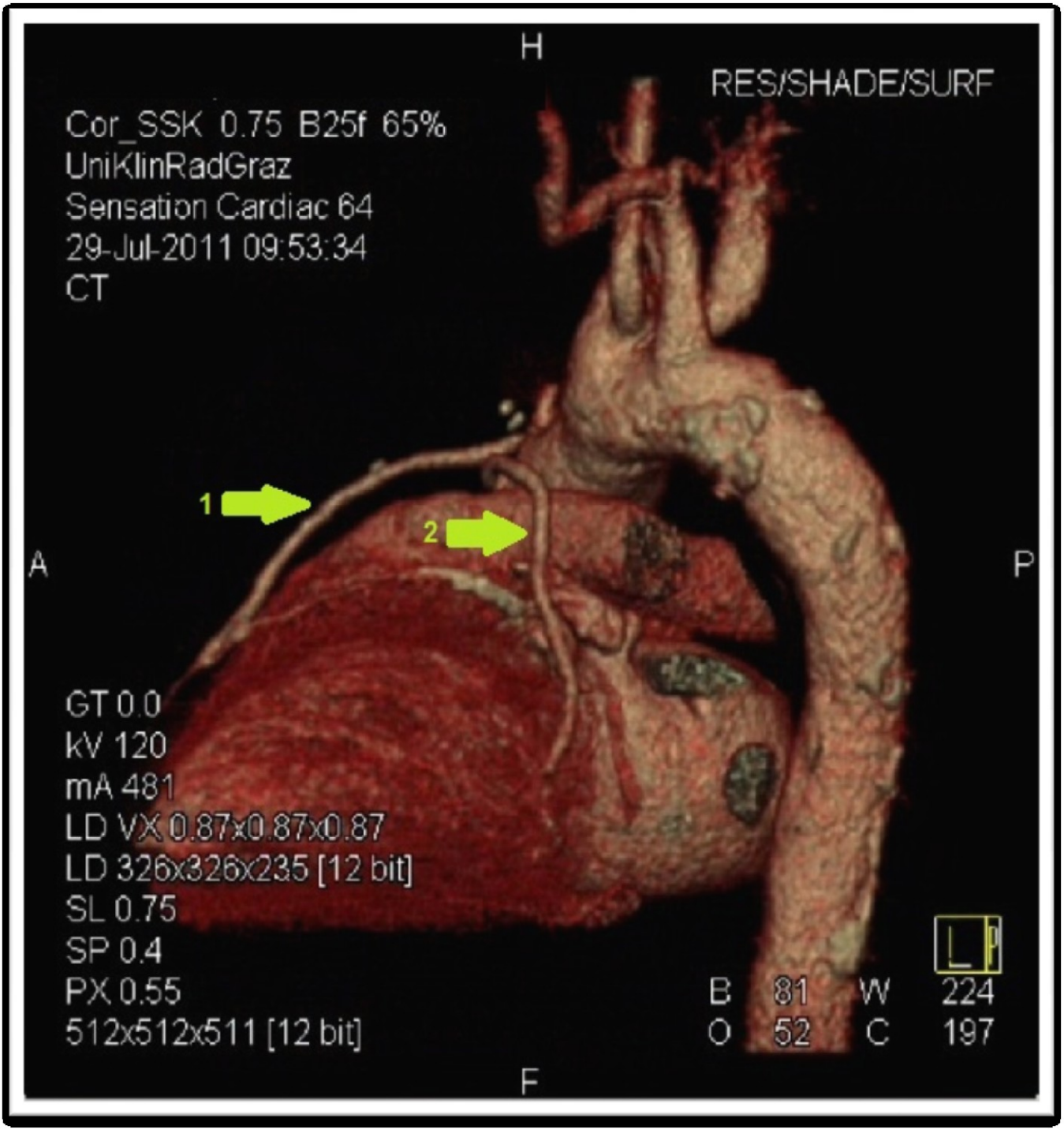

Figure 7: 3D-reconstruction (Patient 5);

1: LAD bypass graft; 2: OM bypass graft

3.2.6. Patient Six

3.2.6.1. Indication for alternative conduits

The patient presented with progredient angina pectoris in 2010 with state after posterior myocardial infarction, PCI and LAD- Stenting. The coronary angiography showed complete stent- occlusion in the LAD as well as a 70% stenosis in the LM, 75% stenosis in the CX and 90% stenosis in the RCA. With state after bilateral varicose vein surgery GSV grafts were not available, instead the SSV was harvested bilaterally.

The patient received a LIMA-to-LAD bypass and SSV-bypasses to RCX and RCA.

3.2.6.2. Results of CT coronary angiography

The contrast-enhanced CT scans showed a patent LIMA-to-LAD bypass (Fitzgibbon B). The venous CX-bypass is patent as well (Fitzgibbon B); the RCA bypass is not displayed and therefore considered as occluded (Fitzgibbon A).

Unfortunately, a 3D reconstruction was not available for this patient.

3.2.7. Patient Seven

3.2.7.1. Indication for alternative conduits

This patient presented with persistent angina pectoris in 2009 with state after myocardial infarction. The coronary angiography showed an occluded RCA and significant stenoses in LAD and CX. The GSV was not available due to a bilateral varicose vein surgery, with a massive generalized atherosclerosis arterial graft alternatives (except a LITA graft) were not advisable either, which is why the SSV was harvested and used as conduit.

The patient received a LITA-to-LAD bypass and two SSV bypass grafts to the RCX and the RCA.

3.2.7.2. Results of CT coronary angiography

In the contrast-enhanced CT scan all three bypass grafts (LITA-to-LAD, SSV conduits to distal RCA and proximal CX) appeared patent, accordingly Fitzgibbon B.

Figure 7 shows the 3D-reconstuction of the Cardiac CT scan.

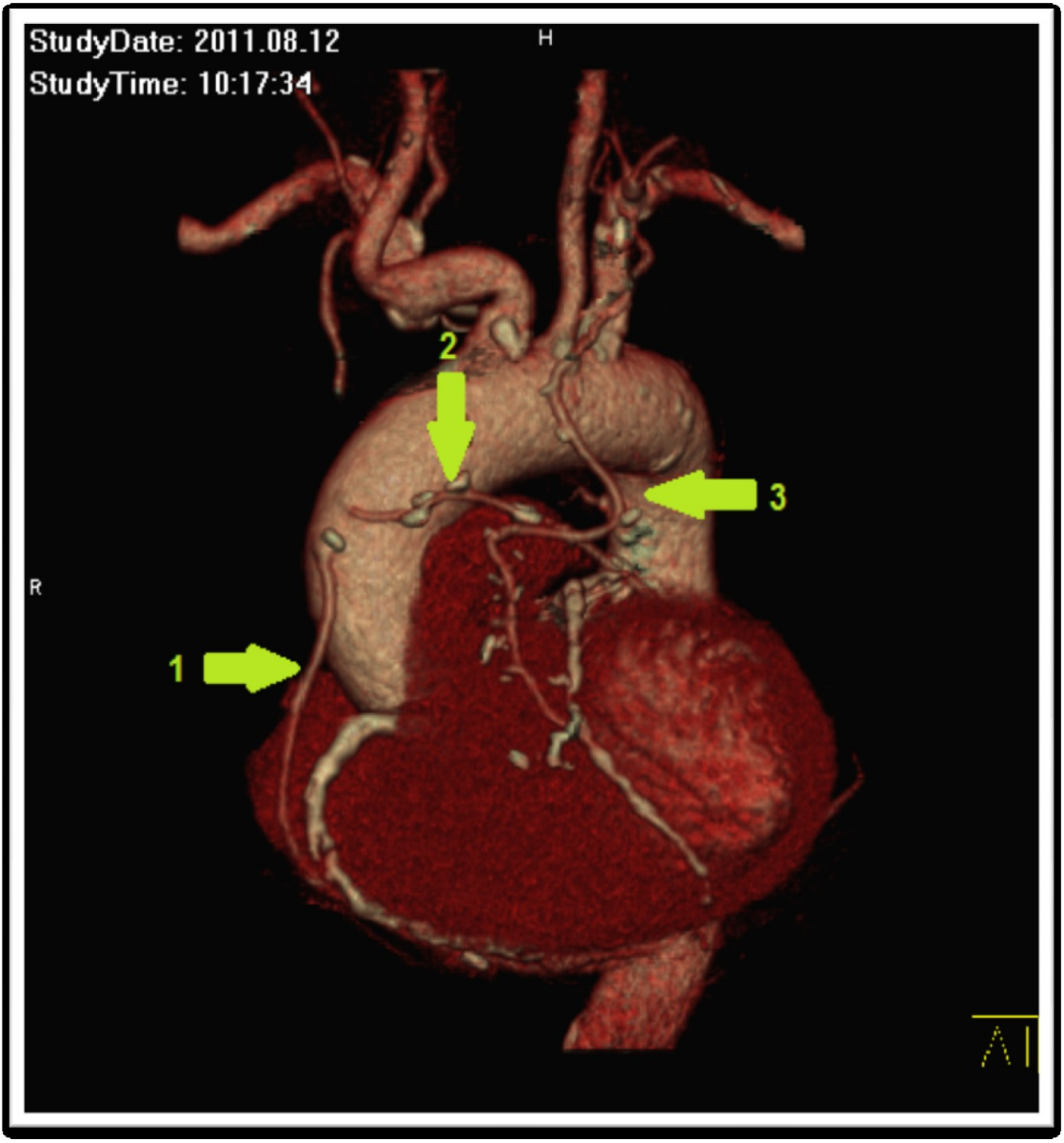

Figure 8: 3D-reconstruction (Patient 7);

1:SSV conduit to RCA; 2: SSV conduit to RCX; 3: LIMA-to-LAD bypass graft

3.3. Results of conventional coronary angiography

3.3.1. Patient Eight

3.3.1.1. Indication for alternative conduits

The patient presented herself with acute instable angina pectoris with dyspnea at rest in 2008. An acute PCA showed 50% LAD stenosis and a completely occluded RCA, the indication for an emergency CABG was set. Intraoperatively the GSV appeared with a relatively large caliber, it was therefore coated with external biocompound-mesh.

The patient received two venous biocompound-supported GSV bypass grafts to the LAD and the RCA.

3.3.1.2. Results of coronary angiography

The patient presented in 2010, two years after her surgery, in the casualty department of the university hospital in Graz with instable angina.

The acute PCI showed the two venous bypass grafts (target vessels LAD and RCA) were occluded (Fitzgibbon A).

Figure 9 shows the coronary angiography with a complete stenosis of the bypass grafts.

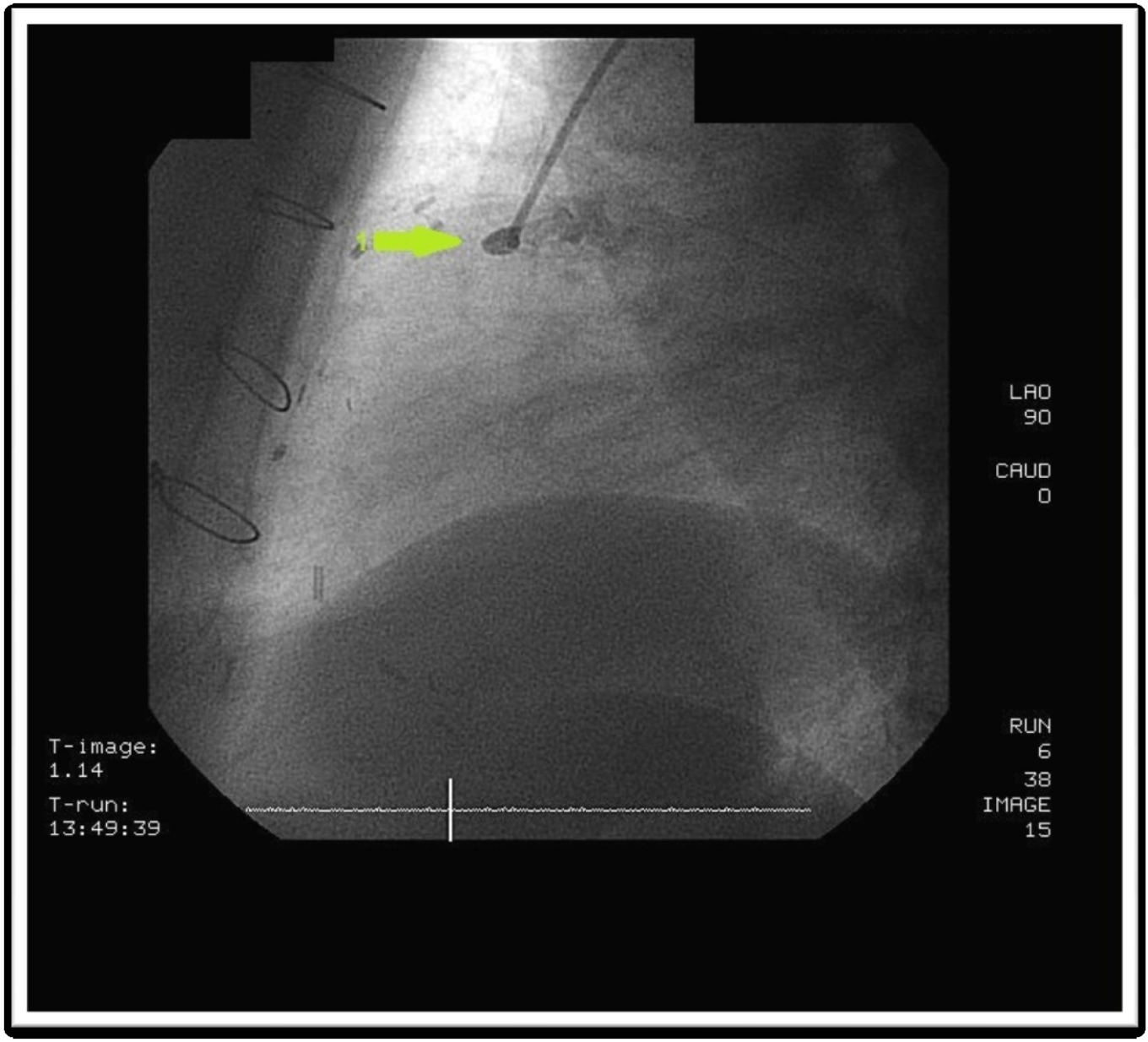

Figure 9: Coronary angiography (Patient 8); 1: Complete occlusion of bypass graft

3.3.2. Patient Nine

3.3.2.1. Indication for alternative conduits

The patient presented with acute retrosternal pain and dyspnea in 2008. Biochemically and by ECG a myocardial infarction could be proved, an acute coronary angiography showed an occluded LAD and significant stenoses in the CX and RCA, which set the indication for an emergency CABG. Intraoperatively the harvested GSV turned out to be varicose, wherefore it was coated with an external biocompound mesh.

The patient received three biocompound-supported GSV bypass grafts to LAD, CX and RCA.

3.3.2.2. Results of coronary angiography

The patient presented one year after her surgery in the casualty unit with instable angina. She showed no pathological changes in the ECG, but biochemically a NSTEMI was proven.

The acute PCI proved a 50% stenosis of the LM and an occlusion of two bypass grafts leading to LAD and RCA (Fitzgibbon A). The third bypass leading to the CX appeared patent (Fitzgibbon B, see Figure 10).

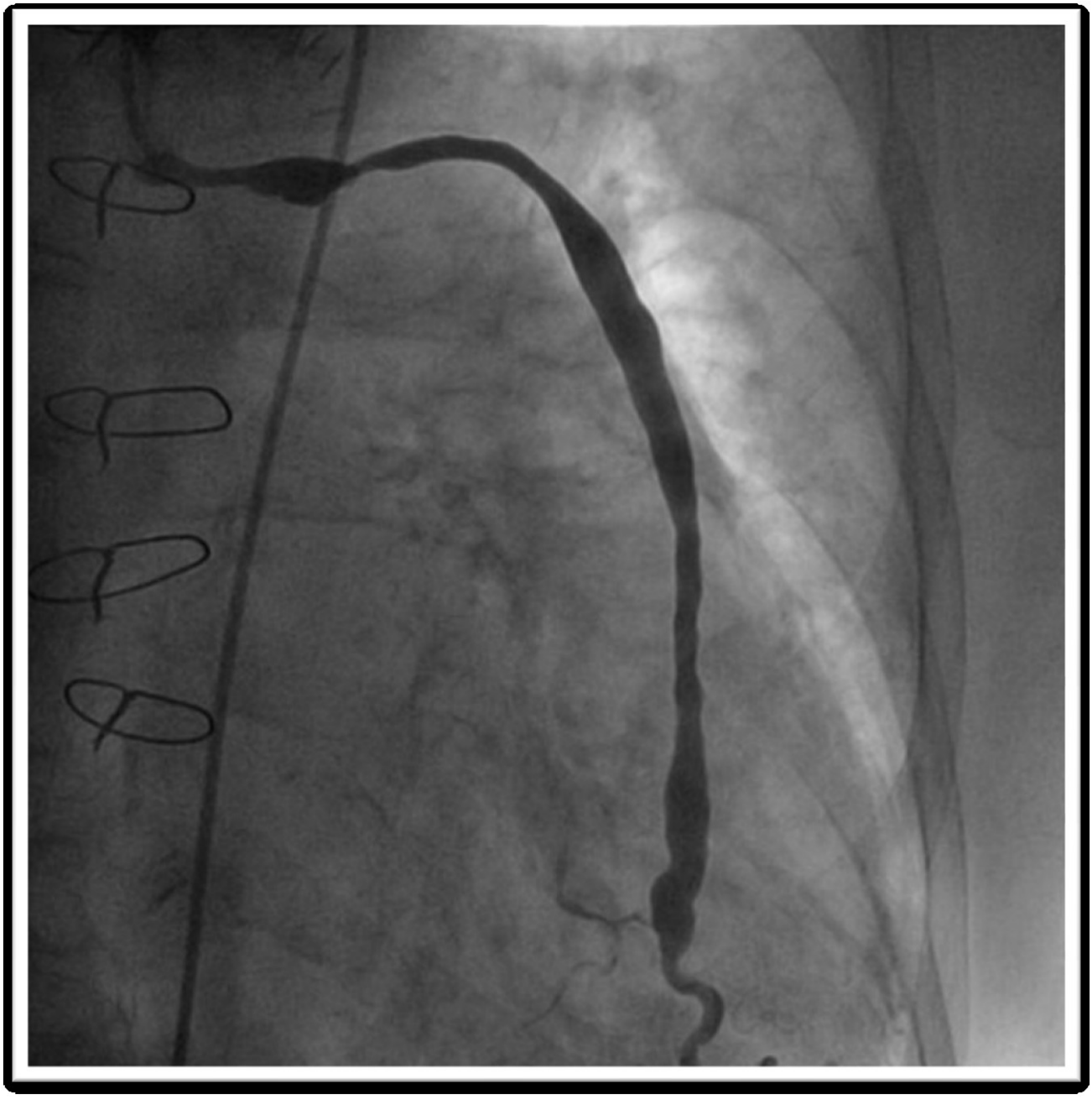

Figure 10: Coronary angiography of Patient Nine; CX bypass graft patent but with significant wall irregularities.

3.3.3. Patient Ten

3.3.3.1. Indication for alternative conduits

The patient presented with atypical angina pectoris and dyspnea in 2009. The coronary angiography showed significant proximal LAD- (90%) and ALA- (90%) stenosis.

After an acute PCI with stent implantation in LAD and DX with early stent thrombosis and increasingly unstable condition the patient was set for an emergency CABG. As for the emergency conditions, a preoperatively known peripheral artery disease (PAD) which excluded arterial graft material and aspects of bilateral varicosis, that could not be ruled out preoperatively, the CV was harvested in first place. As it appeared to be rather thin-walled it was coated by a biocompound-mesh.

The patient received two biocompound-supported CV bypass grafts, one to the LAD and one to the DX.

3.3.3.2. Results of coronary angiography

The patient presented 6 month after surgery with instable angina pectoris at the casualty department. Biochemically a NSTEMI was proven.

The emergency PCI showed the LAD-stent occluded, a 90% re-stenosis of the DX and the LAD- and DX-bypasses occluded (Fitzgibbon A).

Figure 11 shows the outlines of the biocompound external mesh used to support the (occluded) bypass grafts.

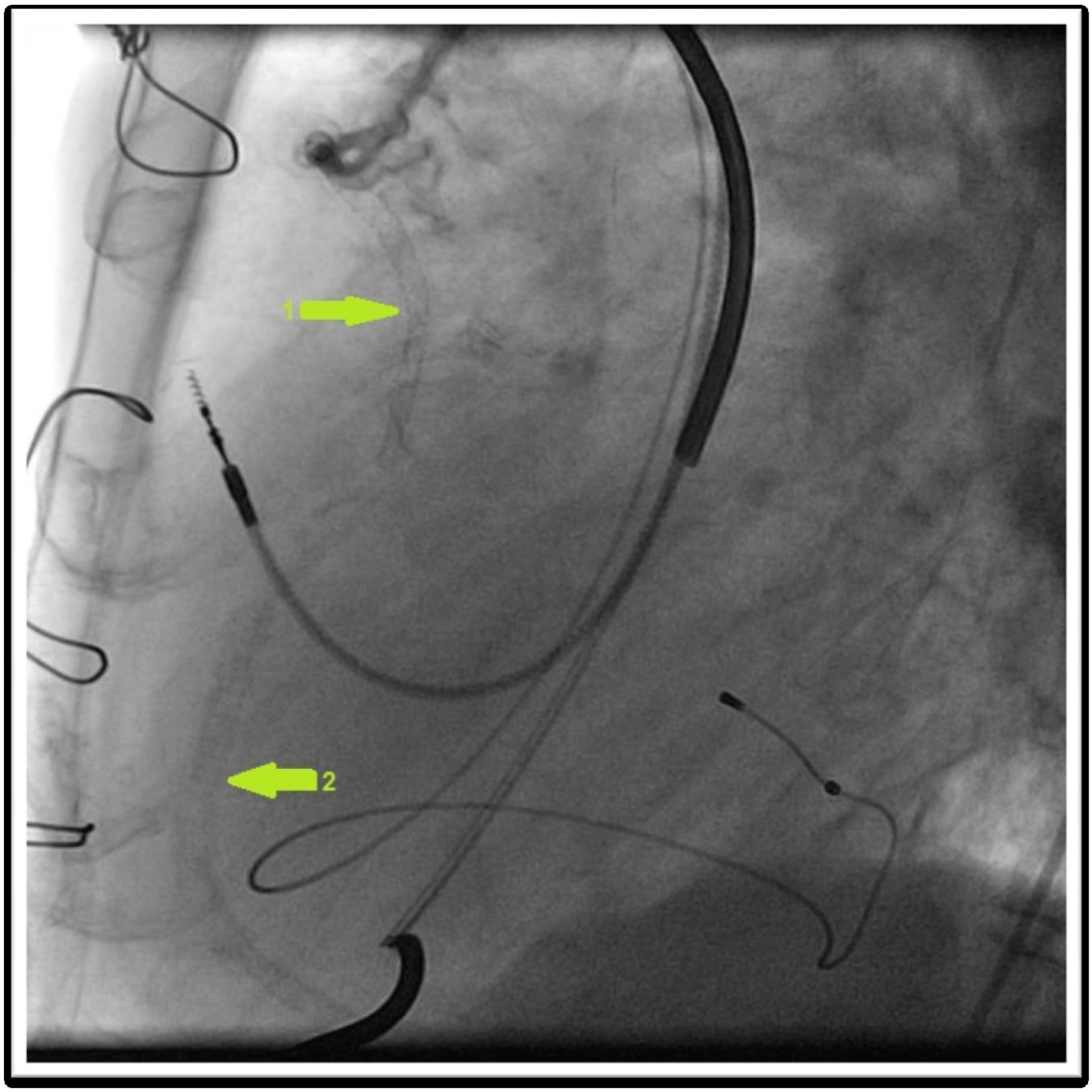

Figure 11: Coronary angiography of Patient Ten; Both biocompound-supported vein grafts occluded. 1 and 2 show the outlines of the biocompound external mesh.

3.4. Results of graft patency

The ten patients with postoperative follow-up (either CT (n=7) or coronary angiography (n=3)) received altogether 20 bypass grafts with alternative conduits.

All in all, from the 20 bypass grafts 6 were made using the CV (5 patients), 6 by using the SSV (4 patients) and 8 of them using the biocompound-supported GSV (3 patients) as a conduit.

Figure 6 shows the distribution of the bypass grafts to the individual groups.

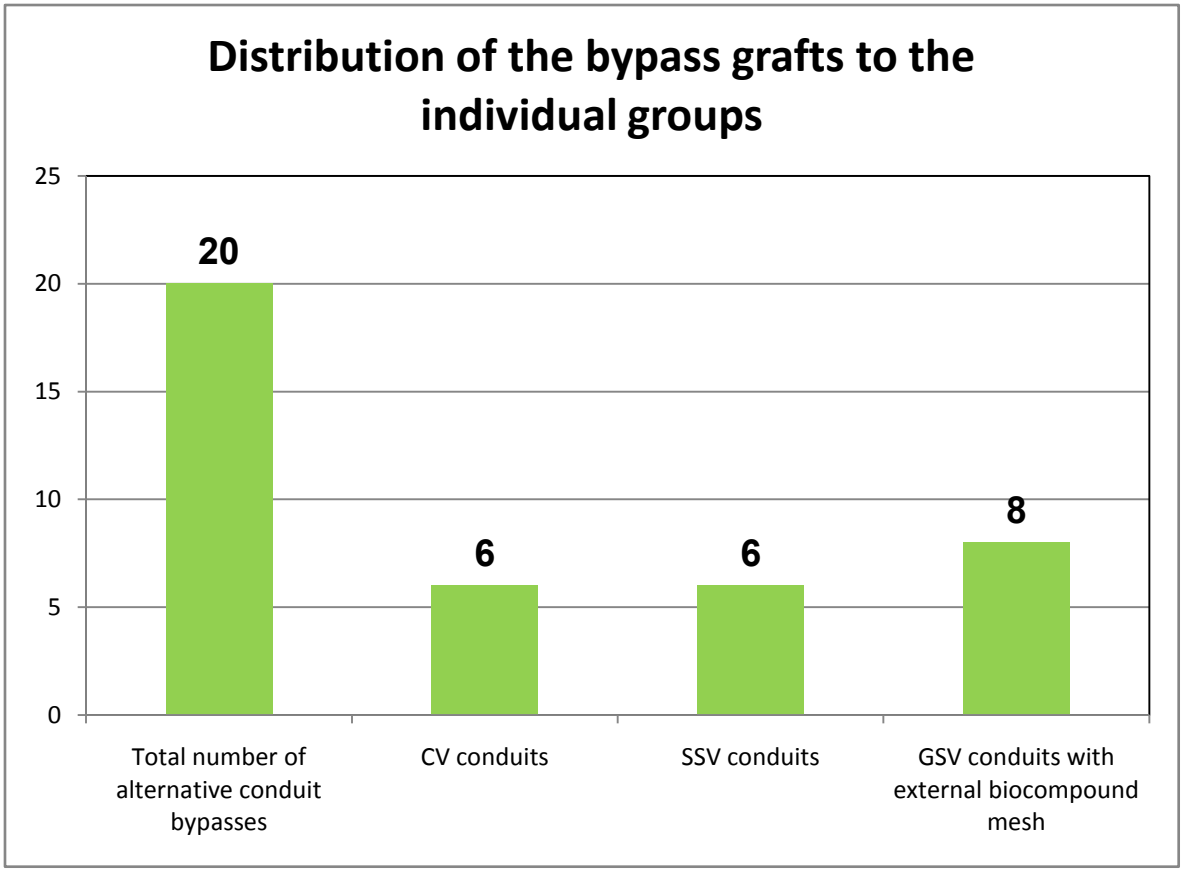

Figure 12: Distribution to the individual groups

The assessment of the bypass graft patency is based on the Fitzgibbon criteria with Fitzgibbon A means > 50% stenosis and therefore counts as occluded and Fitzgibbon B means <50% stenosis and therefore counts as patent.

3.4.1. Overall patency of alternative conduits

In a total of 20 alternative bypass grafts, only nine appeared patent (Fitzgibbon A) and 11 appeared occluded (Fitzgibbon B) in the follow-up examinations (CT and coronary angiography), giving a rate of 45% patency (see Fig.7).

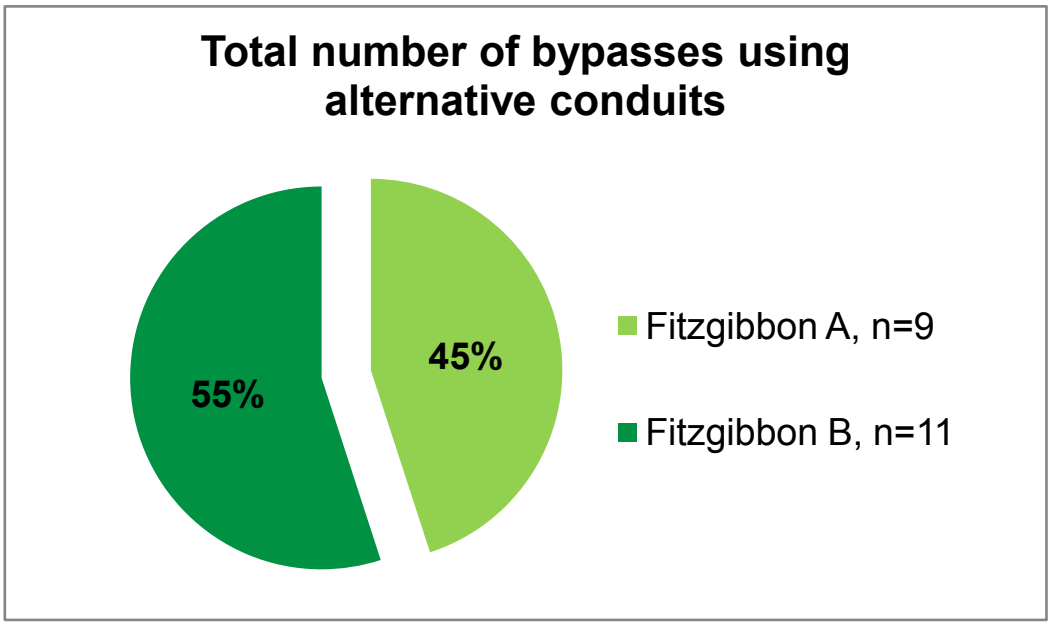

Figure 13: Overall Patency of alternative bypass conduits

3.4.2. Cephalic vein conduits

In two patients both the CV and the SSV were used as conduits and were harvested simultaneously during surgery, which made it impossible to assign the created bypass grafts to the actual used conduit afterwards.

From the total of six CV conduits, only four could be assigned definitely. In the follow-up examinations none of the four CV conduits appeared patent (Fitzgibbon A: n=0; Fitzgibbon B: n=4; patency rate 0%, see Fig. 8).

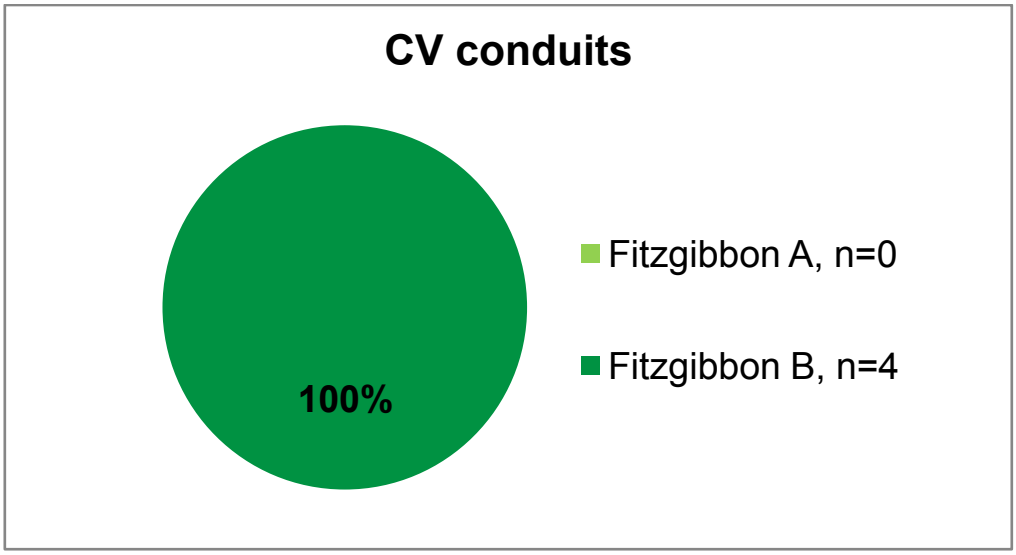

Figure 14: Patency of CV conduits

3.4.3. Small saphenous vein conduits

Two of the six SSV conduits used in our patients could not be assigned definitely. From the remaining four bypass grafts three remained patent (Fitzgibbon A) in the follow-up and one appeared occluded (Fitzgibbon B) which equals a patency rate of 75% (see Fig. 9).

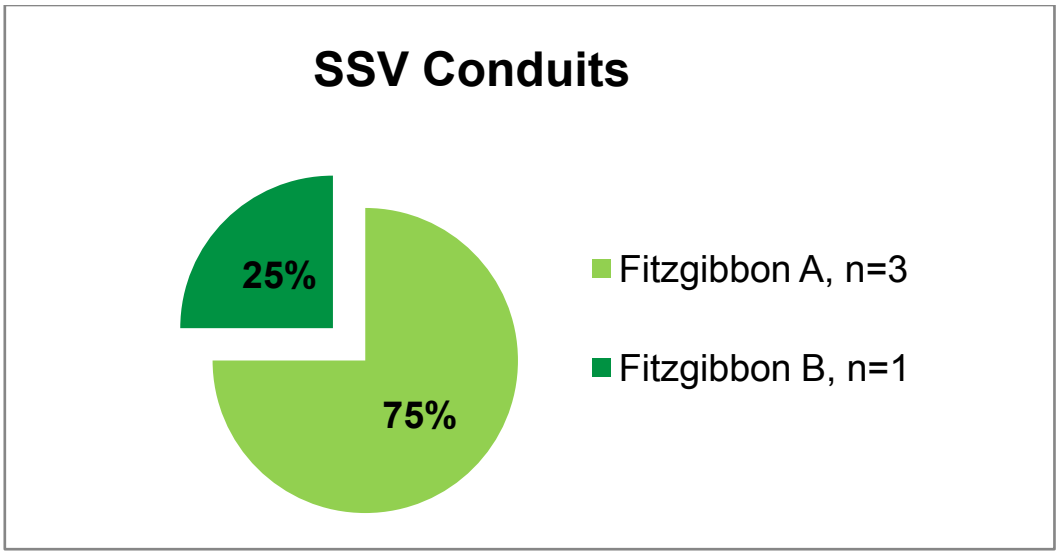

Figure 15: Patency of SSV conduits

3.4.4. Biocompound-supported vein grafts

Three patients received a GSV conduit with external biocompound mesh. At a total of eight bypass grafts, three appeared patent in the examination (Fitzgibbon A) and five appeared occluded (Fitzgibbon B). This equals a patency rate of 37,5% (see Fig. 10).

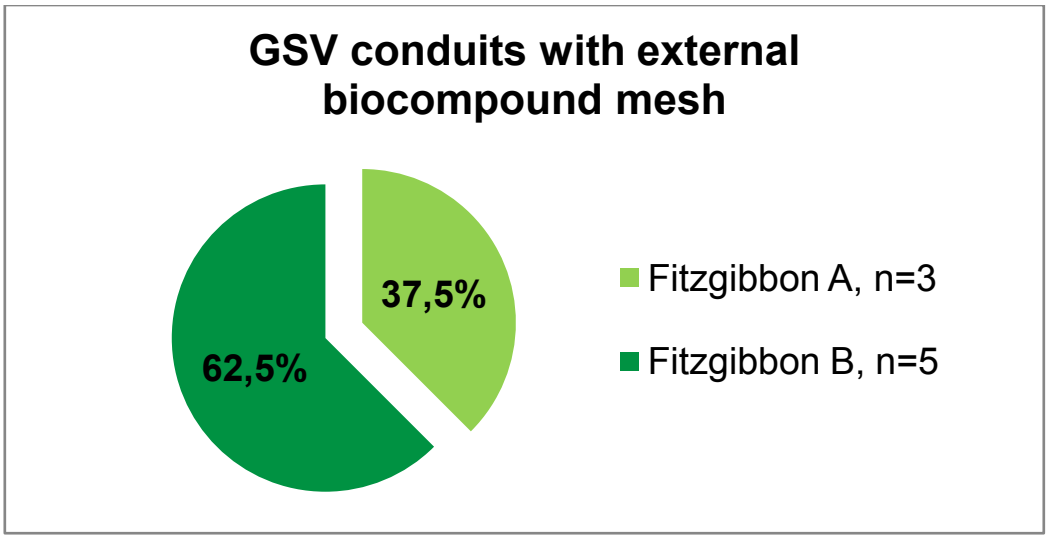

Figure 16: Patency of GSV conduits

3.4.5. Summary

Figure 11 shows a summary of all bypass grafts and the three groups of alternative conduits.

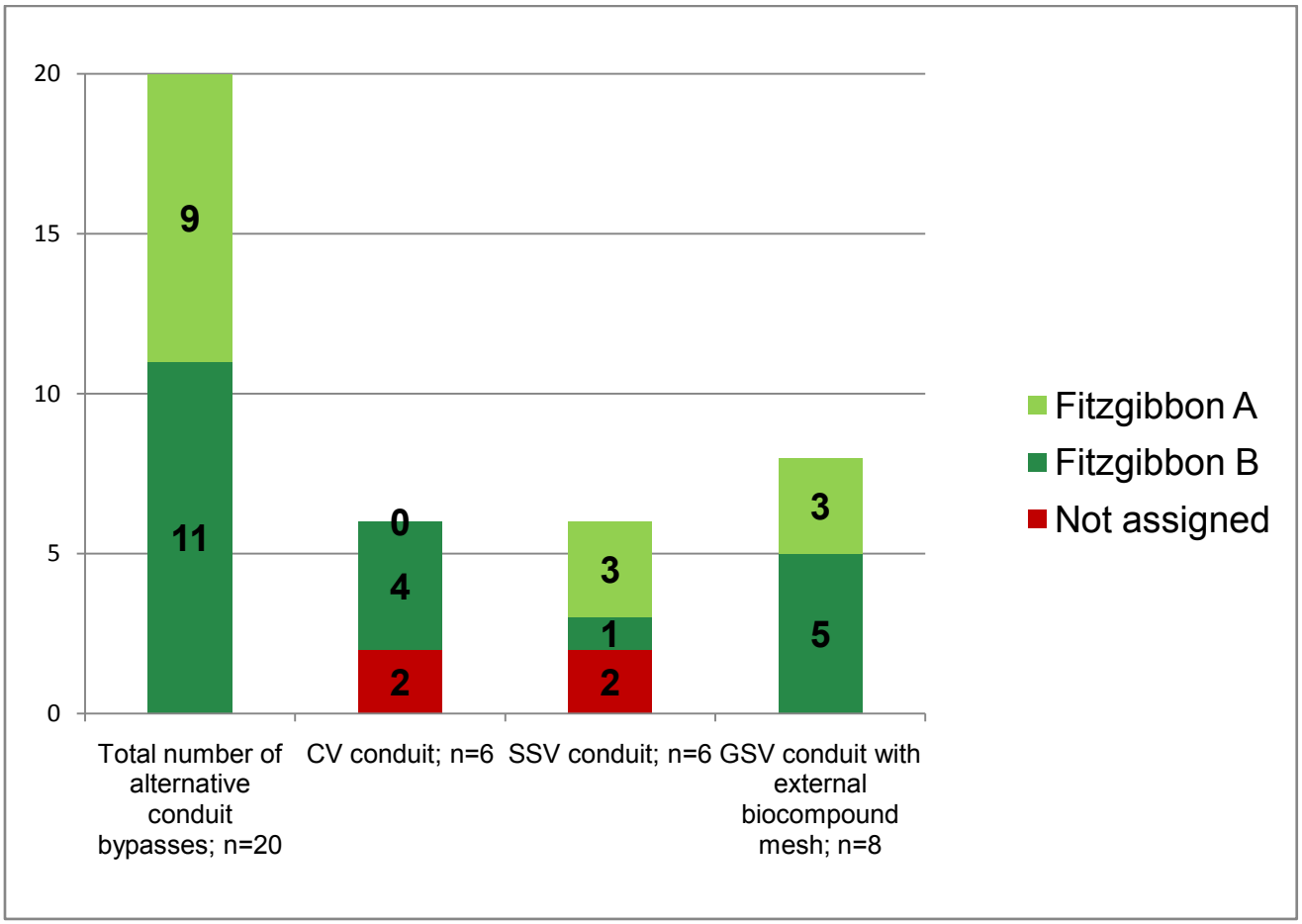

Figure 17: Bypass grafts in total and subdivided in the three groups

In Table 5 the different grafts types and the patency rates according to our study are summarized.

Graft types	Fitzgibbon A	Fitzgibbon B	Patency rate
Altogether alternative bypass grafts	9	11	**45%**
SSV conduits	0	4	**0%**
CV conduits	3	1	**75%**
GSV conduits with biocompound mesh	3	5	**37,5%**

Table 5: Patency rates of the different graft types

3.5. Evaluation of questionnaire results

The twelve patients that were invited for CT coronary angiography answered the provided questionnaire (Mac New health related quality of life instrument, available at Annex).

The questionnaire contains 27 items (= global scale), which can be divided into three subitems: an emotional scale (12 items), a social scale (11 items) and a physical scale (5 items). Every question is answered by using a 7-point Likert scale to objectify the answers, in which 1 means the poorest and 7 the best quality of life. The analysis is performed by determination of the average value for each patient, once for each scale (global scale, emotional, social and physical scale). (13,52)

According to Heller at al. (54) an average value of < 5,0 is associated with a decreased quality of life.

3.5.1. Global scale

On the global scale, the twelve surveyed patients achieved an average score of 5,6, which means a good quality of life. Only three patients achieved average values of less than 5,0, which goes along with a decreased life quality.

Table 5 shows the patients´ answers on each question (=global scale) and the average values determined from these data.

Patient	1	2	3	4	5	6	7	8	9	10	11	12
Item												
1	6	7	4	6	4	5	6	4	4	3	7	6
2	7	7	5	7	5	6	7	4	4	4	7	7
3	7	7	6	5	5	6	6	4	2	4	7	7
4	7	7	5	6	5	6	7	6	3	3	7	7
5	6	7	3	6	3	5	7	2	3	3	7	7
6	6	7	4	5	4	6	5	3	4	3	5	4
7	7	7	4	4	4	4	6	4	5	3	7	4
8	6	7	5	6	4	5	7	7	2	3	7	4
9	7	7	7	7	3	6	5	5	7	4	5	5
10	7	7	6	7	6	7	7	7	7	7	7	7
11	7	7	7	7	4	7	7	4	7	3	7	4
12	7	7	7	6	6	5	7	6	2	2	7	5
13	7	7	7	6	7	7	7	5	4	3	7	7
14	6	7	6	7	3	6	7	4	4	7	5	4
15	7	7	6	6	6	7	6	7	4	4	7	6
16	7	5	5	7	3	4	7	4	3	4	5	4
17	7	4	6	7	3	7	6	7	7	n.a.	5	3
18	6	7	5	7	5	6	7	6	7	4	7	7
19	7	7	4	5	4	7	7	4	4	4	6	4
20	7	7	4	6	5	5	6	6	6	6	7	4
21	7	7	4	5	6	6	7	7	4	n.a	7	3
22	2	5	6	7	3	6	7	6	4	2	7	6
23	7	7	6	6	4	7	7	4	4	7	7	7
24	7	7	6	7	4	4	7	7	4	6	7	7
25	7	7	5	7	6	6	7	6	4	4	6	7
26	7	7	5	6	3	6	7	6	6	4	7	5
27	n.a.	7	n.a	n.a.	5	3	n.a.	n.a.	n.a.	1	7	4
Average value	**6,6**	**6,7**	**5,3**	**6,2**	**4,4**	**5,7**	**6,6**	**5,2**	**4,4**	**3,9**	**6,6**	**5,4**

Table 6: MacNew Questionnaire to quality of life; Answers and average value

3.5.2. Emotional scale

The emotional scale includes 12 items, thematizing symptoms like frustration, fear, sadness and general satisfaction, to objectify the patients´ current emotional state and to recognize signs of depression related with their disease.

Table 7 shows the items, themes, answers and the average value of each patient.

	Patient	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Item													
1	Frustration	6	7	4	6	4	5	6	4	4	3	7	6
2	Worthlessness	7	7	5	7	5	6	7	4	4	4	7	7
3	Confidence	7	7	6	5	5	6	6	4	2	4	7	7
4	Discouraged and depressed	7	7	5	6	5	6	7	6	3	3	7	7
5	Relaxed	6	7	3	6	3	5	7	2	3	3	7	7
6	Exhausted	6	7	4	5	4	6	5	3	4	3	5	4
7	Satisfied with their lives	7	7	4	4	4	4	6	4	5	3	7	4
8	Anxious	6	7	5	6	4	5	7	7	2	3	7	4
10	Weepy	7	7	6	7	6	7	7	7	7	7	7	7
13	Feeling of others being less confident	7	7	7	6	7	7	7	5	4	3	7	7
15	Lack of confidence	7	7	6	6	6	7	6	7	4	4	7	6
18	Fearful	6	7	5	7	5	6	7	6	7	4	7	7
	Average Value	**6,6**	**7,0**	**5,0**	**5,9**	**4,8**	**5,8**	**6,5**	**4,9**	**4,1**	**3,7**	**6,8**	**6,1**

Table 7: Emotional scale; Questions, individual answers and average values

The average value on the emotional scale is 5,6. Eight patients achieved average values higher than 5,0, associated with good quality of life, four patients achieved values less than 5,0, associated with lower quality of life.

3.5.3. Social scale

The social scale contains eleven items with attention on family situation and social support in terms of their disease.

Table 8 provides the data to the social scale with questions, answers and average values of each individual patient.

	Patient	1	2	3	4	5	6	7	8	9	10	11	12
Item													
11	Dependence	7	7	7	7	4	7	7	4	7	3	7	4
12	Social Activities	7	7	7	6	6	5	7	6	2	2	7	5
17	Physical limitation in Sports	7	4	6	7	3	7	6	7	7	n.a.	5	3
20	Restriction in social activity	7	7	4	6	5	5	6	6	6	6	7	4
21	Uncertain about physical activity	7	7	4	5	6	6	7	7	4	n.a.	7	3
22	Overprotective family	2	5	6	7	3	6	7	6	4	2	7	6
23	Load for others	7	7	6	6	4	7	7	4	4	7	7	7
24	Feel excluded	7	7	6	7	4	4	7	7	4	6	7	7
25	Social restriction	7	7	5	7	6	6	7	6	4	4	6	7
26	Physical restriction	7	7	5	6	3	6	7	6	6	4	7	5
27	Sexual activity	n.a.	7	n.a.	n.a.	5	3	n.a.	n.a.	n.a.	1	7	4
Average Value		**6,5**	**6,5**	**5,6**	**6,4**	**4,5**	**5,6**	**6,8**	**5,9**	**4,8**	**3,9**	**6,7**	**5,0**

Table 8: Social scale; Questions, individual answers and average values

The average value in the social scale is 5,7. Nine patients achieved average values higher than 5,0 (good quality of life) and three patients are considered to have a decreased life quality (average value less than 5,0).

3.5.4. Physical scale

The physical scale includes five items and puts its emphasis on physical symptoms that correspond with angina pectoris or cardiac insufficiency.

Table 10 shows the physical scale with questions, answers and average values of each of the twelve surveyed patients.

	Patient	1	2	3	4	5	6	7	8	9	10	11	12
Item													
6	Exhausted	6	7	4	5	4	6	5	3	4	3	5	4
9	Dyspnea	7	7	7	7	3	6	5	5	7	4	5	5
14	Chest pain	6	7	6	7	3	6	7	4	4	7	5	4
16	Tired, Leg pain	6	7	6	7	3	6	7	4	4	7	5	4
19	Drowsiness, dizziness	7	7	4	5	4	7	7	4	4	4	6	4
Average Value		**6,4**	**7,0**	**5,4**	**6,2**	**3,4**	**6,2**	**6,2**	**4,0**	**4,6**	**5,0**	**5,2**	**4,2**

Table 9: Physical Scale; Questions, individual answers and average values

The average value of all twelve patients in the physical scale is 5,3, which is associated with a good quality of life. Four patients achieved values less than 5,0, associated with decreased life quality, eight patients are considered to have a good quality of life (average values above 5,0).

3.5.5. Summary

Figure 12 shows the distribution of patients in the different scales (global, emotional, social and physical scale) and the assignment due to average values to either good or decreased quality of life.

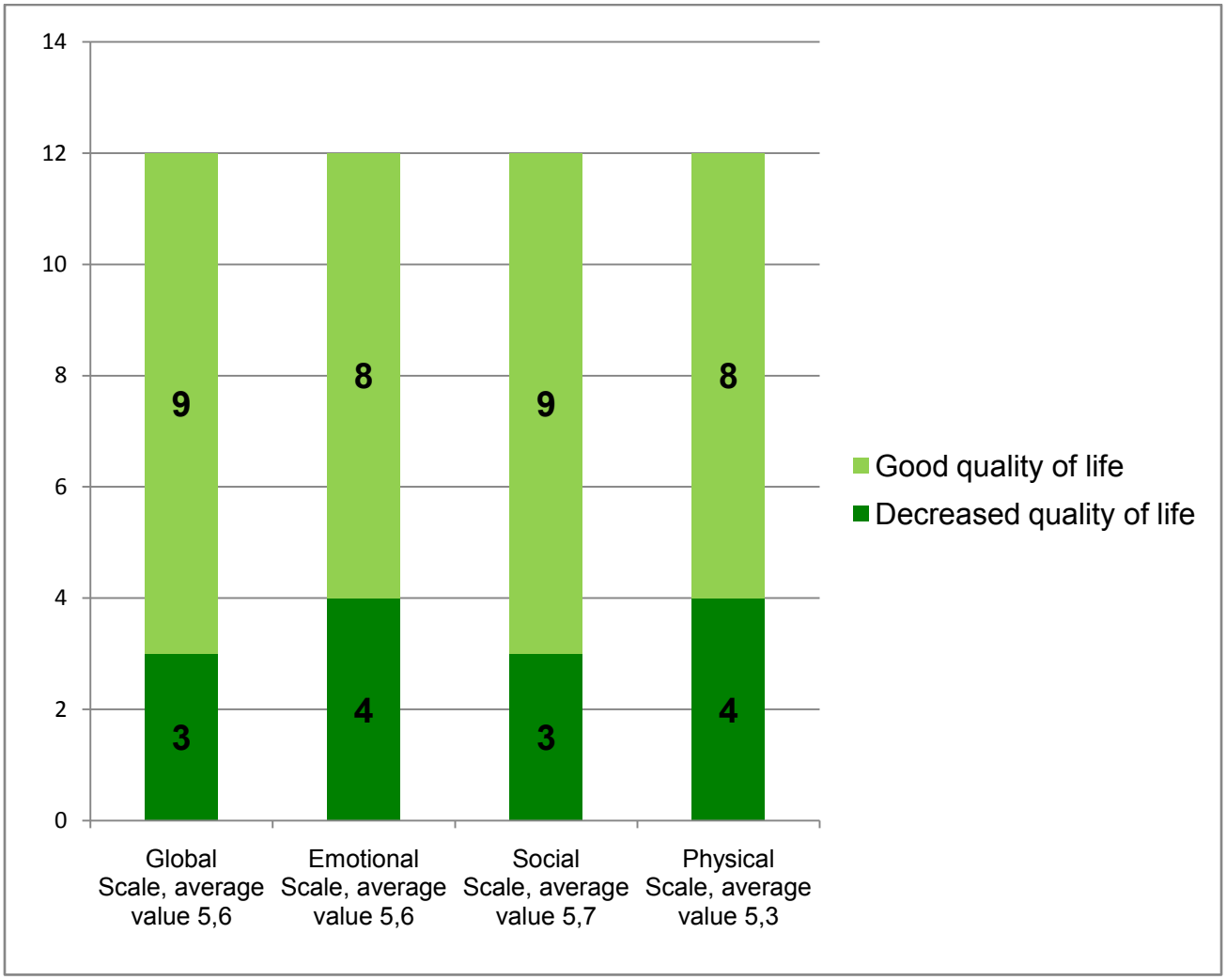

Figure 18: Overview of the distribution of patients in the different scales; limit value between good and decreased quality of life = 5,0

With average values of more than 5,0 nine patients can be considered to have a good quality of life, according to the global scale. Subdivided into emotional, social and physical scale, eight out of twelve patients are in a good emotional and physical condition and nine out of twelve patients are satisfied with their social lives and family support. These results are, in view of the patients´ diseases and prehistory, very satisfactory.

4. Discussion

4.1. CT coronary angiography

Routine examination of the bypass patency, both in short-term as well as in the long term is not part of standard follow-up after bypass surgery. So far the only way to evaluate the patency of the coronary angiography was the coronary angiography, which, for being an invasive examination, is not justified as a follow-up.

By now very advanced technique of CT scanners and the immense progress in the depiction of coronary arteries in cardiac CT a follow-up to evaluate the patency of grafts after surgery is possible today without invasive measures. According to some studies, the specificity and sensitivity of a 64-slice CT in the representation of occlusions and stenoses of up to 100% is possible. (55-59)

4.2. Long-term results for conventional bypass grafts

4.2.1. Internal thoracic artery

The left internal thoracic artery (LITA) is the most commonly used conduit in coronary artery bypass grafting (CABG) and represents the current gold standard of CABG conduits. Many studies prove excellent patency rates for LITA grafts with up to 90% after ten years, associated with improved survival (28-30,32,60).

Rright internal thoracic artery (RITA) grafts show similar, yet slightly poorer results in terms of short-term as well as long-term patency. According to Tranbaugh et al (38) long-term patency of RITA grafts is 80%, which is almost equivalent to long-term patency of LITA grafts.

Current studies examine the use of a bilateral internal thoracic artery (ITA) graft. As both LITA and RITA show the best patency rates compared to any other, especially venous, conduits (28-30,32,38,60,61), bilateral ITA grafts for myocardial revascularization seemed to be the best option to obtain optimal long-term results in both graft patency and peri- and postoperative mortality and morbidity. Studies have demonstrated that expanding ITA use to using RITA, radial artery (RA) and bilateral

ITA grafts (using RITA as pedicle or free graft) is clearly exceeding GSV grafts. (31,35,36,62)

Nevertheless, due to higher rates of sternal infection, sternal dehiscence and postoperative mediastinitis, bilateral ITA grafts should be avoided in elderly, obese and/or diabetic patients (which applies to a large part of cardiosurgical patients) (38).

4.2.2. Radial artery

The radial artery (RA) was introduced by Carpentier in 1971 (39) as an arterial alternative to GSV grafts to increase long-term survival in cardiosurgical patients, as arterial conduits showed better patency results compared to venous conduits. As RA grafts initially showed higher occlusion rates than GSV grafts utilized in the same procedure (45) they were abandoned only two years later, but revitalized by Acar et al (41) after discovering a patent RA bypass after 15 years thus being thought to be occluded. Current studies provide long-term patency results of 82- 100% for RA conduits, which clearly exceeded those of GSV (38,41-49)

4.2.3. Great saphenous vein

Besides LITA grafts the great saphenous vein (GSV) is routinely used in CABG, though it shows poor long-term patency results. Due to intimal hyperplasia and accelerated sclerosis up to 15 % of GSV grafts are occluded in one year (43), and by ten years at least 50% show significant disease (28,39). Patency rates for GSV grafts are satisfactory in the early postoperative period (up to 90%), but decrease over time and result in patency rates of only 50% after 10-15 years .(6,10,11,40,61)

4.3. Long-term results for alternative bypass grafts

4.3.1. Short saphenous vein

The short saphenous vein (SSV) as an alternative to ITA and/or GSV grafts became popular in the late 1970s and early 1980s, but so far received very little mention in current literature (12). In patients with varicosis of both lower legs surgeons often switch to harvest the SSV instead of GSV, though largely lacking of viable long-term patency results.

The current literature differs between the SSV being a viable alternative though lacking of further angiographic data (10,11) and showing significant occlusion rates compared to other, especially GSV, conduits (49).

This study was primarily conducted to validate the long-term patency of various alternative grafts, including the SSV. Of the six patients that received a SSV conduit and were examined postoperatively, two grafts could not be assigned; of the remaining four grafts three were patent and only one occluded, which equals a patency rate of 75%.

Chang et al. (7) examined the patency of 91 SSV conduits, 18 of them used in CABG, and demonstrated a two-year patency rate of 77%. In 1993 Chang et al (6) reported the short-term clinical use of 31 SSV conduits in 25 patients, compared to a control group of 25 patients with GSV conduits, showing no significant differences in terms of operative mortality and morbidity between the two groups. Postoperative angiography was not performed, so due to missing patency results, the study´s validity is limited.

Foster and Kranc (3) reported a patency rate of 65% in 26 patients with SSV conduits after six years. Other studies only referred to a very small series of patients with SSV conduits used for CABG, and reporting of the procedural success was mainly based on clinical outcome and was not validated by coronary angiography.

4.3.2. Cephalic veins

The suitability of cephalic vein (CV) grafts is controversial, as they are known to be thin-walled and therefore predestined to suffer from traumatic damage during harvesting and tend to kinking, twisting and aneurysmatical dilatation. In our study all four examined CV grafts were occluded, which equals a patency rate of 0%.

Other studies demonstrated patency rates from 50 to 90% (14-22,40). Licht et al (14) demonstrated a CV conduit patency rate of 52% in a follow-up of 18 patients, though 39% angiographically showed intraluminal disease and 19% of the CV conduits were dilated. Prieto et al (18) presented a small series of ten patients with different intervals of follow up examination and found an early (less than six month after surgery) patency rate of 90%, after more than one year the patency of CV grafts decreased to 63%. Seifert et al (19) had 17 patients with a total of 35 CV conduits in an eight month follow up, in which 66% of the CV grafts remained patent. Jarvinen et al (17) demonstrated a 87% patency rate (16 veins in 15 patients, average interval to surgery 1,4 years). As Wijnberg et al (15) compared 28 patients with CV conduits to a control group with GSV conduits on an average of 4,6 years follow up, he discovered CV patency rates of 47% compared to a 77% patency of GSV grafts.

The probably most significant study to date, due to its highest number of participants, was performed by Stoney et al (16). He examined 56 upper extremity vein grafts in 28 patients in an average interval of 25 month and demonstrated patency rates of 57%, though 12,5% of the CV conduits presented with localized stenosis.

4.3.3. Biocompound-supported venous grafts

All so far published reports concerning biocompound-supported vein grafts are limited by small patient numbers and are mostly - as it is the case in our series - small case series, wherefore long-term patency results of biocompound-supported GSV grafts still remain unclear. In our series we examined three patients with a total of eight biocompound-supported GSV grafts. Five grafts were occluded and only three patent, which equals a patency rate of 37.5%.

Zurbrügg et al (63) demonstrated the effectiveness of external sheathing to prevent intimal and medial thickening of vein grafts in a pig model. Four weeks after implanting biocompound-supported vein grafts in carotid arteries of pigs the biocompound-supported vein grafts showed significantly less intimal and medial thickening than the control group with native vein grafts. A second experimental series, implanting biocompound-supported vein grafts using a dog model of aortocoronary bypass grafting (24) confirmed the initial results, as the average thickness of biocompound-supported vein grafts 30 days after implantation was significantly lower than in a control group with native vein grafts, demonstrating that external sheathing of vein grafts prevent intimal and medial thickening after bypass surgery.

The first clinical experiences with biocompound-supported vein grafts are promising. Zurbrügg et al (25) presented a series with 18 patients receiving 43 biocompound-supported vein grafts and suggested at least acceptable long-term patency results, analyzing clinical outcomes in terms of freedom from signs and symptoms of myocardial ischemia. Nevertheless, results are limited due to lack of angiographic data.

The first long-term results were published in 2000 by Zurbrügg et al (23). 200 patients received biocompound-supported grafts, 53 were examined three years after surgery. LITA grafts showed, as expected, superior patency results (97,3%) compared to venous grafts. The patency rates of biocompound-supported vein grafts were 68,3% and did not differ significantly from the results for native vein graft patency (68.7%) (23).

4.4. Conclusion

Alternative graft material is increasingly used due to the growing number of patients with comorbidities that exclude conventional grafts. The choice of which alternative conduit to be harvested is currently determined by the preference of the surgeon. Our study should provide reliable results for long-term patency of alternative graft material to enable evidence based decision-making in the future. Due to the small number of participants the study and the results for long-term patency are limited.

Summarizing the results of our study and the current existing literature dealing with alternative graft material, neither CV, SSV or biocompound-supported GSV grafts achieve comparable results in terms of long-term patency as the conventional grafts do. Though biocompound-supported GSV grafts seem promising, further long-term data is needed to confirm their suitability.

At the current state of knowledge alternative conduits, in comparison to the conventional conduits, show poorer long-term patency results and therefore should only be used when all other conduit options have been exhausted.

5. References

(1) Buxton BF, Hayward PA, Newcomb AE, Moten S, Seevanayagam S, Gordon I. Choice of conduits for coronary artery bypass grafting: craft or science? Eur J Cardiothorac Surg 2009 Apr;35(4):658-670.

(2) Canver CC. Conduit options in coronary artery bypass surgery. Chest 1995 Oct;108(4):1150-1155.

(3) Foster ED, Kranc MA. Alternative conduits for aortocoronary bypass grafting. Circulation 1989 Jun;79(6 Pt 2):I34-9.

(4) Roskamm H, Neumann F-J, KaluscheD, BesteholmH-P. Herzkrankheiten: Pathophysiologie, Diagnostik, Therapie. 5th ed. Berlin, Heidelberg, New York: Springer-Verlag; 2004. p. 483-484.

(5) Jacob S, Kallikourdis A, El-Shafei H, Dunning J. What is the patency of the short saphenous vein when used for coronary artery bypass grafting? Interact Cardiovasc Thorac Surg 2007 Dec;6(6):783-785.

(6) Chang BB, Ferraris VA, Sadoff J, Shah DM, Leather RP, Berry WR, et al. Alternative conduits for coronary revascularization: a novel approach for harvest of the lesser saphenous vein. Cardiovasc Surg 1993 Jun;1(3):280-284.

(7) Chang BB, Paty PS, Shah DM, Leather RP. The lesser saphenous vein: an underappreciated source of autogenous vein. J Vasc Surg 1992 Jan;15(1):152-6; discussion 156-7.

(8) Crosby IK, Craver JM. The lesser saphenous vein. An alternative graft for coronary revascularization. Ann Thorac Surg 1975 Dec;20(6):703-705.

(9) Goyal A, Shah PM, Babu SC, Mateo RB. Popliteal-crural bypass through the posterior approach with lesser saphenous vein for limb salvage. J Vasc Surg 2002 Oct;36(4):708-712.

(10) Raess DH, Mahomed Y, Brown JW, King RD. Lesser saphenous vein as an alternative conduit of choice in coronary bypass operations. Ann Thorac Surg 1986 Mar;41(3):334-336.

(11) Salerno TA, Charrette EJ. The short saphenous vein: an alternative to the long saphenous vein for aortocoronary bypass. Ann Thorac Surg 1978 May;25(5):457-458.

(12) Sarwar U, Chetty G, Sarkar P. The short saphenous vein: a viable alternative conduit for coronary artery bypass grafts harvested using a novel technical approach. J Surg Tech Case Rep 2012 Jan;4(1):61-63.

(13) MacNew health related quality of life instrument. 2013; Available at: http://www.macnew.org/wp/. Accessed 24.01.2013, 2013.

(14) Licht P, Jacobsen E, Lerbjerg G, Andersen PE, Alstrup P. Cephalic veins in coronary artery bypass surgery. Eur J Cardiothorac Surg 1996;10(5):327-330.

(15) Wijnberg DS, Boeve WJ, Ebels T, van Gelder IC, van den Toren EW, Lie KI, et al. Patency of arm vein grafts used in aorto-coronary bypass surgery. Eur J Cardiothorac Surg 1990;4(9):510-513.

(16) Stoney WS, Alford WC,Jr, Burrus GR, Glassford DM,Jr, Petracek MR, Thomas CS,Jr. The fate of arm veins used for aorta-coronary bypass grafts. J Thorac Cardiovasc Surg 1984 Oct;88(4):522-526.

(17) Jarvinen A, Harjula A, Mattila S, Valle M, Harjola PT. Experience with arm veins as aorto-coronary bypass grafts. J Cardiovasc Surg (Torino) 1984 Jul-Aug;25(4):344-347.

(18) Prieto I, Basile F, Abdulnour E. Upper extremity vein graft for aortocoronary bypass. Ann Thorac Surg 1984 Mar;37(3):218-221.

(19) Seifert D., Bircks W, Jehle J SH. Aorto-coronary bypass grafts using cephalic veins. Thorac Cardiovasc Surg 1982(37):218-221.

(20) Faries PL, Arora S, Pomposelli FB,Jr, Pulling MC, Smakowski P, Rohan DI, et al. The use of arm vein in lower-extremity revascularization: results of 520 procedures performed in eight years. J Vasc Surg 2000 Jan;31(1 Pt 1):50-59.

(21) Mehta S, Levine S, Margolis JR, Martin JC, Krauthamer D, Traad E. Long-term patency of arterialized cephalic vein used as a conduit for coronary artery bypass grafting. Cathet Cardiovasc Diagn 1991 Jul;23(3):208-210.

(22) Schulman ML, Badhey MR. Late results and angiographic evaluation of arm veins as long bypass grafts. Surgery 1982 Dec;92(6):1032-1041.

(23) Zurbrugg HR, Knollmann F, Musci M, Wied M, Bauer M, Chavez T, et al. The biocompound method in coronary artery bypass operations: surgical technique and 3-year patency. Ann Thorac Surg 2000 Nov;70(5):1536-1540.

(24) Zurbrugg HR, Musci M, Sanger S, Gutersohn A, Mulling C, Wellnhofer E, et al. Prevention of venous graft sclerosis with clopidogrel and aspirin combined with a mesh tubing in a dog model of arteriovenous bypass grafting. Eur J Vasc Endovasc Surg 2001 Oct;22(4):337-341.

(25) Zurbrugg HR, Hetzer R. The use of biocompound-grafts together with varicose veins. First clinical experience. J Cardiovasc Surg (Torino) 1996 Dec;37(6 Suppl 1):143-146.

(26) Joint Task Force on Myocardial Revascularization of the European Societey of Cardiologists (ESC) and the European Association for Cardio-Thoracic Surgery

(EATCS). Joint ESC-EACTS-Guidelines on myocardial revascularization. Eur Heart J 2010(31):2501-2555.

(27) Kerry Bryant. Section 20: Conduit for Coronary Bypass Grafting Selection, Evaluation, and Harvesting
. Available at: http://ctpa2b.com/lectures/sess20/sess20.htm. Accessed Juni/Juli, 2012.

(28) Lytle BW, Loop FD, Cosgrove DM, Ratliff NB, Easley K, Taylor PC. Long-term (5 to 12 years) serial studies of internal mammary artery and saphenous vein coronary bypass grafts. J Thorac Cardiovasc Surg 1985 Feb;89(2):248-258.

(29) Loop FD, Lytle BW, Cosgrove DM, Stewart RW, Goormastic M, Williams GW, et al. Influence of the internal-mammary-artery graft on 10-year survival and other cardiac events. N Engl J Med 1986 Jan 2;314(1):1-6.

(30) Zeff RH, Kongtahworn C, Iannone LA, Gordon DF, Brown TM, Phillips SJ, et al. Internal mammary artery versus saphenous vein graft to the left anterior descending coronary artery: prospective randomized study with 10-year follow-up. Ann Thorac Surg 1988 May;45(5):533-536.

(31) Cameron AA, Green GE, Brogno DA, Thornton J. Internal thoracic artery grafts: 20-year clinical follow-up. J Am Coll Cardiol 1995 Jan;25(1):188-192.

(32) Cameron A, Davis KB, Green G, Schaff HV. Coronary bypass surgery with internal-thoracic-artery grafts--effects on survival over a 15-year period. N Engl J Med 1996 Jan 25;334(4):216-219.

(33) Sabik JF,3rd, Lytle BW, Blackstone EH, Houghtaling PL, Cosgrove DM. Comparison of saphenous vein and internal thoracic artery graft patency by coronary system. Ann Thorac Surg 2005 Feb;79(2):544-51; discussion 544-51.

(34) Shah PJ, Bui K, Blackmore S, Gordon I, Hare DL, Fuller J, et al. Has the in situ right internal thoracic artery been overlooked? An angiographic study of the radial artery, internal thoracic arteries and saphenous vein graft patencies in symptomatic patients. Eur J Cardiothorac Surg 2005 May;27(5):870-875.

(35) Schmidt SE, Jones JW, Thornby JI, Miller CC,3rd, Beall AC,Jr. Improved survival with multiple left-sided bilateral internal thoracic artery grafts. Ann Thorac Surg 1997 Jul;64(1):9-14; discussion 15.

(36) Tatoulis J, Buxton BF, Fuller JA. Results of 1,454 free right internal thoracic artery-to-coronary artery grafts. Ann Thorac Surg 1997 Nov;64(5):1263-8; discussion 1268-9.

(37) Galbut DL, Traad EA, Dorman MJ, DeWitt PL, Larsen PB, Kurlansky PA, et al. Bilateral internal mammary artery grafts in patients with left main coronary artery disease. J Card Surg 1993 Jan;8(1):18-24.

(38) Tranbaugh RF, Dimitrova KR, Friedmann P, Geller CM, Harris LJ, Stelzer P, et al. Coronary artery bypass grafting using the radial artery: clinical outcomes, patency, and need for reintervention. Circulation 2012 Sep 11;126(11 Suppl 1):S170-5.

(39) Carpentier A, Guermonprez JL, Deloche A, Frechette C, DuBost C. The aorta-to-coronary radial artery bypass graft. A technique avoiding pathological changes in grafts. Ann Thorac Surg 1973 Aug;16(2):111-121.

(40) Curtis JJ, Stoney WS, Alford WC,Jr, Burrus GR, Thomas CS,Jr. Intimal hyperplasia. A cause of radial artery aortocoronary bypass graft failure. Ann Thorac Surg 1975 Dec;20(6):628-635.

(41) Acar C, Jebara VA, Portoghese M, Beyssen B, Pagny JY, Grare P, et al. Revival of the radial artery for coronary artery bypass grafting. Ann Thorac Surg 1992 Oct;54(4):652-9; discussion 659-60.

(42) Reyes AT, Frame R, Brodman RF. Technique for harvesting the radial artery as a coronary artery bypass graft. Ann Thorac Surg 1995 Jan;59(1):118-126.

(43) Fremes SE, Christakis GT, Del Rizzo DF, Musiani A, Mallidi H, Goldman BS. The technique of radial artery bypass grafting and early clinical results. J Card Surg 1995 Sep;10(5):537-544.

(44) Zacharias A, Habib RH, Schwann TA, Riordan CJ, Durham SJ, Shah A. Improved survival with radial artery versus vein conduits in coronary bypass surgery with left internal thoracic artery to left anterior descending artery grafting. Circulation 2004 Mar 30;109(12):1489-1496.

(45) Fisk RL, Brooks CH, Callaghan JC, Dvorkin J. Experience with the radial artery graft for coronary artery bypass. Ann Thorac Surg 1976 Jun;21(6):513-518.

(46) Buxton BF, Raman JS, Ruengsakulrach P, Gordon I, Rosalion A, Bellomo R, et al. Radial artery patency and clinical outcomes: five-year interim results of a randomized trial. J Thorac Cardiovasc Surg 2003 Jun;125(6):1363-1371.

(47) Moran SV, Baeza R, Guarda E, Zalaquett R, Irarrazaval MJ, Marchant E, et al. Predictors of radial artery patency for coronary bypass operations. Ann Thorac Surg 2001 Nov;72(5):1552-1556.

(48) Desai ND, Cohen EA, Naylor CD, Fremes SE, Radial Artery Patency Study Investigators. A randomized comparison of radial-artery and saphenous-vein coronary bypass grafts. N Engl J Med 2004 Nov 25;351(22):2302-2309.

(49) Khot UN, Friedman DT, Pettersson G, Smedira NG, Li J, Ellis SG. Radial artery bypass grafts have an increased occurrence of angiographically severe stenosis and occlusion compared with left internal mammary arteries and saphenous vein grafts. Circulation 2004 May 4;109(17):2086-2091.

(50) Cohn JD, Korver KF. Selection of saphenous vein conduit in varicose vein disease. Ann Thorac Surg 2006 Apr;81(4):1269-1274.

(51) KIPS BAY MEDICAL I. null. 2010; Available at: http://www.faqs.org/sec-filings/100520/Kips-Bay-Medical-Inc_S-1.A/#b. Accessed 08. Februar, 2013.

(52) Gramm Lukas, Meffert Cornelia, Farin Erik, Jäkel Wilfried H. Evaluation der deutschen Version des MacNew Heart Disease Lebensqualitätsfragebogens in der kardiologischen Rehabilitation. Freiburg: Abteilung Qualitätsmanagment und Sozialmedizin, Universitätsklinikum Freiburg; 2008.

(53) Siemens AG MS. Get the eintire picture; Somatom Sensation Cardiac 64; 2004; Available at: http://www.medical.siemens.com/siemens/en_US/gg_ct_FBAs/files/brochures/CT_SOMATOM_Sensation_Cardiac_64.pdf. Accessed 24.01.2013, 2013.

(54) Heller Richard F, Lim Lynette, Valenti Lisa, Knapp June. **Predictors of quality of life after hospital admission for heart attack or angina**. International journal of cardiology 1997 18. April 1997;59(2):161-166.

(55) Naveed T, Ayub M, Nazeer M, Mallick NH, Mohydin BS, Ali Z. Role of 64-slice multi detector computed tomography for non-invasive visualisation of coronary artery bypass grafts for follow up in post CABG patients. J Ayub Med Coll Abbottabad 2010 Apr-Jun;22(2):13-19.

(56) Pache G, Saueressig U, Frydrychowicz A, Foell D, Ghanem N, Kotter E, et al. Initial experience with 64-slice cardiac CT: non-invasive visualization of coronary artery bypass grafts. Eur Heart J 2006 Apr;27(8):976-980.

(57) Ropers D, Pohle FK, Kuettner A, Pflederer T, Anders K, Daniel WG, et al. Diagnostic accuracy of noninvasive coronary angiography in patients after bypass surgery using 64-slice spiral computed tomography with 330-ms gantry rotation. Circulation 2006 Nov 28;114(22):2334-41; quiz 2334.

(58) Malagutti P, Nieman K, Meijboom WB, van Mieghem CA, Pugliese F, Cademartiri F, et al. Use of 64-slice CT in symptomatic patients after coronary bypass surgery: evaluation of grafts and coronary arteries. Eur Heart J 2007 Aug;28(15):1879-1885.

(59) Laynez-Carnicero A, Estornell-Erill J, Trigo-Bautista A, Valle-Munoz A, Nadal-Barange M, Romaguera-Torres R, et al. Non-invasive assessment of coronary artery bypass grafts and native coronary arteries using 64-slice computed tomography: comparison with invasive coronary angiography. Rev Esp Cardiol 2010 Feb;63(2):161-169.

(60) Boylan MJ, Lytle BW, Loop FD, Taylor PC, Borsh JA, Goormastic M, et al. Surgical treatment of isolated left anterior descending coronary stenosis. Comparison of left internal mammary artery and venous autograft at 18 to 20 years of follow-up. J Thorac Cardiovasc Surg 1994 Mar;107(3):657-662.

(61) Fitzgibbon GM, Kafka HP, Leach AJ, Keon WJ, Hooper GD, Burton JR. Coronary bypass graft fate and patient outcome: angiographic follow-up of 5,065 grafts related to survival and reoperation in 1,388 patients during 25 years. J Am Coll Cardiol 1996 Sep;28(3):616-626.

(62) Fiore AC, Naunheim KS, Dean P, Kaiser GC, Pennington G, Willman VL, et al. Results of internal thoracic artery grafting over 15 years: single versus double grafts. Ann Thorac Surg 1990 Feb;49(2):202-8; discussion 208-9.

(63) Zurbrugg HR, Wied M, Angelini GD, Hetzer R. Reduction of intimal and medial thickening in sheathed vein grafts. Ann Thorac Surg 1999 Jul;68(1):79-83.

Annex - Questionnaire

macnew.org
HEALTH-RELATED QUALITY OF LIFE INSTRUMENT

Wir würden Ihnen nun gerne einige Fragen stellen, wie Sie sich **während der letzten 2 Wochen** gefühlt haben.

Bitte kreuzen Sie jenes Feld ☐ an, welches zu Ihrer Antwort passt.

1. Wie oft haben sie sich in den letzten 2 Wochen frustriert, ungeduldig oder ungehalten gefühlt?

1	☐	DIE GANZE ZEIT
2	☐	DIE MEISTE ZEIT
3	☐	EINEN GROSSTEIL DER ZEIT
4	☐	MANCHMAL
5	☐	SELTEN
6	☐	KAUM
7	☐	NIE

2. Wie oft haben Sie sich in den letzten 2 Wochen wertlos oder unzulänglich gefühlt?

1	☐	DIE GANZE ZEIT
2	☐	DIE MEISTE ZEIT
3	☐	EINEN GROSSTEIL DER ZEIT
4	☐	MANCHMAL
5	☐	SELTEN
6	☐	KAUM
7	☐	NIE

3. Wie oft haben Sie sich in den letzten 2 Wochen sehr zuversichtlich und sicher gefühlt, mit Ihrem Herzproblem umgehen zu können?

1	☐	NIE
2	☐	WENIGE MALE
3	☐	MANCHMAL
4	☐	ZIEMLICH OFT
5	☐	MEISTENS
6	☐	FAST IMMER
7	☐	IMMER

4. Wie oft haben Sie sich im Allgemeinen in den letzen 2 Wochen entmutigt oder deprimiert gefühlt?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5 ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

5. Wie oft in den vergangenen 2 Wochen fühlten Sie sich entspannt und ohne Druck?

1 ❑ NIE
2 ❑ WENIGE MALE
3 ❑ MANCHMAL
4 ❑ ZIEMLICH OFT
5 ❑ MEISTENS
6 ❑ FAST IMMER
7 ❑ IMMER

6. Wie oft in den letzten 2 Wochen fühlten Sie sich erschöpft oder mit wenig Energie?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5 ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

7. Wie glücklich und zufrieden sind Sie in den letzten 2 Wochen mit Ihrem persönlichen Leben gewesen?

1 ❑ SEHR UNZUFRIEDEN; DIE MEISTE ZEIT UNGLÜCKLICH
2 ❑ IM ALLGEMEINEN UNZUFRIEDEN, UNGLÜCKLICH
3 ❑ IRGENDWIE UNZUFRIEDEN, UNGLÜCKLICH
4 ❑ IM ALLGEMEINEN ZUFRIEDEN
5 ❑ DIE MEISTE ZEIT GLÜCKLICH
6 ❑ DIE MEISTE ZEIT SEHR GLÜCKLICH
7 ❑ ABSOLUT GLÜCKLICH, HÄTTE NICHT ZUFRIEDENER SEIN KÖNNEN

8. Wie oft haben Sie sich in den letzten 2 Wochen rastlos gefühlt oder so, als ob Sie Schwierigkeiten hätten, ruhig zu werden?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5 ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

9. Wie stark war Ihre Atemnot in den letzten 2 Wochen während Ihrer alltäglichen Aktivitäten?

1 ❑ EXTREME ATEMNOT
2 ❑ SEHR HOHE ATEMNOT
3 ❑ ZIEMLICHE ATEMNOT
4 ❑ MITTELMÄSSIGE ATEMNOT
5 ❑ ETWAS ATEMNOT
6 ❑ WENIG ATEMNOT
7 ❑ KEINE ATEMNOT

10. Wie oft in den letzten 2 Wochen haben Sie sich zum Weinen gefühlt?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5 ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

11. Wie oft haben Sie sich in den letzten 2 Wochen abhängiger gefühlt als vor Ihrem Herzproblem?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5 ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

12. Wie oft haben Sie sich in den letzten 2 Wochen außerstande gefühlt, Ihren üblichen gesellschaftlichen Aktivitäten oder denen mit Ihrer Familie nachzukommen?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5. ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

13. Wie oft haben Sie sich in den letzten 2 Wochen so gefühlt, als ob andere nicht mehr dasselbe Vertrauen in Sie haben wie vor Ihren Herzproblemen?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5 ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

14. Wie oft haben Sie in den letzten 2 Wochen Brustschmerzen bei alltäglichen Aktivitäten verspürt?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5 ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

15. Wie oft haben Sie sich in den letzten 2 Wochen unsicher gegenüber sich selbst gefühlt oder ein Mangel an Selbstbewusstsein verspürt?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5 ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

16. Wie oft waren Sie in den letzten 2 Wochen wegen schmerzenden oder müden Beinen beunruhigt?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5 ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

17. Wie stark waren Sie in den letzten 2 Wochen wegen Ihres Herzproblems beim Sport oder beim körperlichen Training eingeschränkt?

1 ❑ SEHR STARK EINGESCHRÄNKT
2 ❑ STARK EINGESCHRÄNKT
3 ❑ ZIEMLICH EINGESCRÄNKT
4 ❑ MÄSSIG EINGESCHRÄNKT
5 ❑ IRGENDWIE EINGESCHRÄNKT
6 ❑ EIN WENIG EINGESCHRÄNKT
7 ❑ ABSOLUT NICHT EINGESCHRÄNKT

18. Wie oft haben Sie sich in den letzten 2 Wochen besorgt oder verängstigt gefühlt?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5 ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

19. Wie oft haben Sie sich in den letzten 2 Wochen schwindlig oder benommen gefühlt?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5 ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

20. Wie stark haben Sie sich in den letzten 2 Wochen wegen Ihres Herzproblems im allgemeinen eingeschränkt oder reduziert gefühlt?

1 ❑ SEHR STARK EINGESCHRÄNKT
2 ❑ STARK EINGESCHRÄNKT
3 ❑ ZIEMLICH EINGESCRÄNKT
4 ❑ MÄSSIG EINGESCHRÄNKT
5 ❑ IRGENDWIE EINGESCHRÄNKT
6 ❑ EIN WENIG EINGESCHRÄNKT
7 ❑ ABSOLUT NICHT EINGESCHRÄNKT

21. Wie oft haben Sie sich in den letzten 2 Wochen unsicher darüber gefühlt, wieviel Gymnastik oder körperliche Aktivitäten Sie machen sollten?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5 ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

22. Wie oft haben Sie in den letzten 2 Wochen Ihre Familie als zu besorgt und zu beschützend empfunden?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5 ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

23. Wie oft in den letzten 2 Wochen fühlten Sie sich, als ob Sie eine Last für andere wären?

1 ❑ DIE GANZE ZEIT
2 ❑ DIE MEISTE ZEIT
3 ❑ EINEN GROSSTEIL DER ZEIT
4 ❑ MANCHMAL
5 ❑ SELTEN
6 ❑ KAUM
7 ❑ NIE

24. Wie oft haben Sie sich in den letzten 2 Wochen wegen Ihres Herzproblems von Aktivitäten mit anderen Leuten ausgeschlossen gefühlt?

1 ☐ DIE GANZE ZEIT
2 ☐ DIE MEISTE ZEIT
3 ☐ EINEN GROSSTEIL DER ZEIT
4 ☐ MANCHMAL
5 ☐ SELTEN
6 ☐ KAUM
7 ☐ NIE

25. Wie oft haben Sie sich in den letzten 2 Wochen unfähig gefühlt, wegen Ihres Herzproblems soziale Kontakte zu pflegen?

1 ☐ DIE GANZE ZEIT
2 ☐ DIE MEISTE ZEIT
3 ☐ EINEN GROSSTEIL DER ZEIT
4 ☐ MANCHMAL
5 ☐ SELTEN
6 ☐ KAUM
7 ☐ NIE

26. In welchem Ausmaß waren Sie im Allgemeinen in den letzten 2 Wochen wegen Ihres Herzproblems bei Ihrer täglichen körperlichen Belastung eingeschränkt?

1 ☐ SEHR STARK EINGESCHRÄNKT
2 ☐ STARK EINGESCHRÄNKT
3 ☐ ZIEMLICH EINGESCRÄNKT
4 ☐ MÄSSIG EINGESCHRÄNKT
5 ☐ IRGENDWIE EINGESCHRÄNKT
6 ☐ EIN WENIG EINGESCHRÄNKT
7 ☐ ABSOLUT NICHT EINGESCHRÄNKT

27. Wie oft in den letzten 2 Wochen hatten Sie das Gefühl, dass Ihr Herzproblem den Sexualverkehr einschränkt oder beeinträchtigt?

1 ☐ DIE GANZE ZEIT
2 ☐ DIE MEISTE ZEIT
3 ☐ EINEN GROSSTEIL DER ZEIT
4 ☐ MANCHMAL
5 ☐ SELTEN
6 ☐ KAUM
7 ☐ NIE
☐ NICHT ZUTREFFEND

Vielen Dank für die Beantwortung der Fragen.