Quality Project 2017
College of Cardiac Surgery

Evolution in use of arterial grafts for CABG in Belgium

Introduction

What is total arterial revascularization?

Coronary artery bypass grafting (CABG) can be performed with arterial and venous conduits. Arterial conduits may consist of the left and right internal mammary artery (LIMA and RIMA), the radial artery (RA) or the right gastro-epiploic artery (RGEA). For venous conduits, the great saphenous vein (SV) from the lower or upper leg is usually utilized.

By the late 1970s it became clear that early SV patency was imperfect and inferior to early and long term IMA patency [(1)] . In 1986, a study documented substantial improvement in clinical outcomes during the first decade after bypass surgery in patients receiving an IMA to LAD graft as compared to those that received SV to LAD grafts [(2)] . During the 1970s, the use of both internal mammary arteries for CABG was still uncommon, but during the 1980s and early 1990s evidence was accumulating that bilateral mammary artery (BIMA) grafting might lead to an improved survival rate [(3,4)] . In the next decade, studies demonstrated a survival benefit for patients that received BIMA of more than 10% at 20 years postoperatively [(5,6)] . Over the past 20 years the use of the radial artery (RA) as the second or third arterial graft after the LIMA has been promoted by several groups, as an alternative to the SV[(7,8)]. The RA is a versatile graft, that can reach all coronary territories, but it is more muscular and vulnerable to spasm compared to the IMA. However, several studies demonstrated at least equal or slightly superior performance of the RA compared to the SV on the mid- and long-term, when it is reserved for target vessels with a stenosis of more than 80-85%. Also in the 1990s, the RGEA had been introduced as an alternative third arterial conduit, but its use nowadays has become somehow less popular, due to its vulnerability, associated diaphragmatic problems, and its tendency to occlude, affected by competitive flow when the target vessel stenosis is less than 90% [(9)] .

Total arterial revascularization (TAR) can be accomplished by combining all these arterial conduits, in different configurations of in situ or Y-grafts, to perform a complete coronary revascularization without the use of SV conduits. Over the last few years, several groups that were early adopters of TAR, have reported a survival advantage of 10% at 10 years after TAR compared to IMA-SV in all patient age cohorts, including older patients [(10,11)] .

What are the benefits?

As pointed out above, the use of BIMA and TAR can improve long-term survival, and lead to fewer non-fatal events (myocardial infarction, recurrent angina), and less need for reintervention. Using exclusively arterial grafts for coronary bypass surgery can overcome the late failure rate of vein grafts: the 10-years patency rate of BIMA is 90-95%, while the SV patency rate rarely exceeds 50-60% at 10 years postoperatively [12] . The 10% survival advantage of BIMA / TAR compared to IMA-SV at 10 years, also seems to be maintained at 20 years (5,6,13), and therefore the use of TAR has particular advantages in patients with a longer life expectancy.

What are the drawbacks?

There is a perception that TAR is technically complex, and that it may not offer benefit to older patients, or to patients with left ventricular dysfunction, diabetes, or established renal failure. It is true that complete arterial bypass grafting to the 3 coronary vessel territories may take some longer operating times, and most of the studies have demonstrated a slightly increased risk on sternal complications (dehiscence, wound infection), particularly in severely obese or insulin dependent diabetic patients [3] . This problem may be partially overcome by using the technique of skeletonization when harvesting the IMA [12] . Overall, less harvest site complications are seen with arterial than with SV harvesting.

Worldwide current data about the use of total arterial revascularization

Not many recent data are available about the current use of BIMA or TAR worldwide.

The 2010 EACTS report (on the period 2006-2008) published numbers about the incidence of (total) arterial grafting from the countries that contributed to the EACTS database [14] . The proportion of coronary surgery utilizing total arterial grafting varied from 0% (Spain) up to a maximum reported rate of 35% (Luxemburg). The incidence of TAR in Belgium is not mentioned in the EACTS 2010 report. The patient's risk profile was inversely related to the number of arterial grafts.

It is often striking that in the same country, a large difference can exist between surgeons and centers. In 2003 at Oxford University Hospital total arterial grafting was used in 80% of patients, but the incidence of TAR in England in 2006 was only 10%. In Austin Hospital, Melbourne, the percentage of TAR increased from 19% in 1995 to 78% in 1998, only as the consequence of a dedicated program initiated by one of the surgeons, and quickly adopted by the whole service [3] .

The USA have always lagged behind on the subject of BIMA and TAR, compared to some European countries. Consecutive data from the STS database reports since 2002 up to 2015 point out that the use of BIMA or TAR is only slowly increasing, but large differences remain [15-17] . In 89% of patients one IMA graft is used. The use of RA and BIMA has only slightly increased over the years, in 2015 they were used in 6,5% and 4,9% of the patients respectively. Still less than 10% of the patients under 55 years of age receive a BIMA, and the incidence decreases with increasing patient age. The use if BIMA grafting was clearly lower when the patient was female, non-white, older and had overweight. TAR is applied in only 2% of the patients under 55 years of age, and in less than 1% of the patients between 65 and 75 years of age. In 2015 in the USA the operative mortality for multiple arterial grafting was comparable to that of a single IMA, however, the incidence of deep sternal wound infections was significantly higher in the BIMA group.

Belgian data about the use of arterial revascularization in 2016

Our analysis is based on data furnished by the Belgian Society of Cardio-Thoracic Surgery (BACTS). The report comprises data from 18 out of the 28 cardiac surgery centers in Belgium. For the analysis we selected patients undergoing primary (redo excluded) isolated CABG during the year 2016. Among 3561 patients treated for isolated CABG, 3493 patients were finally selected after the exclusion of the redo cases.

Bilateral Mammary artery grafting

Among the 3493 patients 1589 (45.4%) received a bilateral mammary artery (BIMA). The use of the different arterial conduits in this study population is shown in Table 1.

Patients who received a BIMA were more commonly male, were younger with less history of myocardial infarction, less diabetes (insulin dependent or not), they had lower creatinine, less COPD, less peripheral vascular disease, less history of CVA, and better mobility (Table 2).

Furthermore, patients in the BIMA group were more in sinus rhythm and had less chance to have atrial fibrillation. They more frequently had three vessel disease and main stem lesions, but less frequently had one and two vessel lesions. They had significantly higher incidence of pulmonary hypertension, shock, salvage operation, or need for inotropic support. The BIMA group had also a higher rate of off-pump revascularization (Table 3).

Total arterial revascularisation

Analysing the data about the distal arterial and venous anastomoses we selected patients that received only arterial grafts (Total Arterial Revascularisation or TAR). From this analysis -taking into account missing data- we concluded that the rate of TAR ranged from 30.4 to 44.7% in our Belgian database. Distribution of the grafts and preoperative characteristics of this group are described in Table 4. Similar to the BIMA population the TAR group was younger with less myocardial infarction, less previous PCI, had less diabetes, COPD, peripheral vascular disease or CVA, and had better mobility and lower creatinine levels.

Subpopulation study

We performed a subgroup analysis dividing the study population in function of age, diabetes status and BMI to obtain greater insight into the use of arterial grafts related to these specific conditions.

Analyzing the diabetes subgroup we found that the use of BIMA or TAR was most common in patients treating their diabetes with diet only or oral diabetic medication. The least BIMA or TAR was used in the insulin dependent diabetes group (Table 5).

The age sub-analysis confirmed the higher use of arterial grafts in younger patients age 60 or less and between 60-70 years of age(Table 6).

No difference in BIMA or TAR use was found among the different BMI groups (Table 7).

Conclusion

Elements necessary to improve and propagate the use of total arterial revascularization

Considering the aforementioned advantages of TAR, and the slow dissipation of the technique, which elements can help to increase the application of TAR in the cardiac surgical community?

1. *Implementation of TAR in the guidelines*

   In the 2014 EACTS/ESC guidelines, the following recommendations were provided [18] :

   - An IMA to LAD is highly recommended (IB)
   - BIMA should be considered in patients younger than 70 years of age (IIaB)
   - The use of the RA is recommended, but only for target vessel stenosis of >70% (IB)
   - TAR is recommended when SV quality is poor, independent of age (IC)
   - TAR can be considered in patients with a life expectancy of >5 years (IIaB)

2. *Emphasizing patient selection to minimize perioperative complications*

   In spite of the clear long-term advantage of BIMA or TAR use, a slightly increased risk on sternal complications is consistently reported in most series. Therefore particular care should be taken in patients with severe obesity (BMI>40), severe chronic obstructive airway disease, and insulin dependent diabetics. However some series reported better outcomes in diabetics with BIMA versus LIMA-SV or PCI.

3. *Enhance surgical training in various multiple arterial grafting techniques and optimize surgical technique*

   TAR requires a meticulous technique and technical imperfections are quickly penalized. Therefore, within a dedicated program, a thorough training of young cardiac surgeons in the particularities of arterial harvesting and bypass configurations is mandatory to obtain a large adoption and success with the technique. Skeletonization of the IMA during harvest, leaving the pleural spaces as intact as possible, or endoscopic techniques for RA harvesting may all help in reducing postoperative morbidity. In the literature no difference is noted when TAR is performed on-pump or off-pump.

4. *Looking beyond short-term outcomes to maximize late patient outcomes*

   The first randomized controlled trial on TAR (the Arterial Revascularization Trial (ART)) found at interim analysis no difference in overall survival and event-free survival at 5 years between patients randomized to receive one or two internal thoracic arteries at the time of surgery[19]. The short-term outcomes however should not dissuade surgeons from the technique of TAR, as the long-term advantages of TAR seem obvious from a large number of observational studies that were published over the last 25 years. Regular feed-back from large databases and registries on positive patient outcomes should stimulate the cardiac surgical community to spend a slightly longer time (in some cases) in the operating theatre to obtain a more optimal result for the patient.

Tables

Table 1. Arterial grafts distribution and number of distal anastomosis in the study population.

	[ALL] N=3493	BIMA N=1589	Non-BIMA N=1904	p-value
Left.IMA	3200 (91.6%)	1589 (100%)	1611 (84.6%)	<0.001
Right.IMA	1615 (46.2%)	1589 (100%)	26 (1.37%)	0.000
RA	53 (1.52%)	35 (2.20%)	18 (0.95%)	0.004
RGEA	6 (0.17%)	2 (0.13%)	4 (0.21%)	0.695
nr.art.anast.	2.26 (2.44)	3.04 (0.92)	1.57 (3.10)	<0.001
nr.venous.anast.	1.17 (1.14)	0.51 (0.74)	1.67 (1.14)	<0.001

The data are expressed as numbers (%), or mean (SD)

Table 2. Preoperative characteristics between BIMA and non-BIMA patients

	[ALL] N=3493	BIMA N=1589	non-BIMA N=1904	p-value
Gender:				<0.001
F	644 (18.4%)	229 (14.4%)	415 (21.8%)	
M	2849 (81.6%)	1360 (85.6%)	1489 (78.2%)	
Age (years)	67.9 (9.77)	64.9 (9.01)	70.4 (9.71)	<0.001
Myoc.Infarction	929 (31.4%)	413 (29.2%)	516 (33.3%)	0.017
PCI	666 (21.9%)	318 (22.1%)	348 (21.8%)	0.889
Diabetes.insul	328 (9.89%)	121 (7.68%)	207 (11.9%)	<0.001
Diabetes.oral	685 (20.6%)	300 (19.0%)	385 (22.1%)	0.033
Dialysis	25 (2.29%)	14 (2.42%)	11 (2.14%)	0.913
Creat in mg%	1.06 (0.54)	1.02 (0.43)	1.10 (0.62)	<0.001
COPD	443 (13.7%)	163 (10.6%)	280 (16.5%)	<0.001
Arteriopathy	635 (20.6%)	252 (17.1%)	383 (23.7%)	<0.001
CVA	287 (11.1%)	111 (8.75%)	176 (13.3%)	<0.001
Poor mobility	0.05 (0.22)	0.04 (0.20)	0.06 (0.24)	0.039
BMI	27.8 (4.41)	27.9 (4.16)	27.7 (4.63)	0.345

The data are expressed as numbers (%), or mean (SD)

Table 3. Perioperative data BIMA vs non-BIMA

	[ALL] N=3374	BIMA N=1585	non-BIMA N=1789	p-value
Sinus rhythm	2860 (88.7%)	1393 (91.6%)	1467 (86.0%)	<0.001
Ventr.tachycardia/fibrillation	12 (0.37%)	7 (0.46%)	5 (0.29%)	0.624
Atrial fibrillation	82 (2.54%)	26 (1.71%)	56 (3.28%)	0.007
Other rhythm	249 (7.72%)	86 (5.66%)	163 (9.55%)	<0.001
One.vessel	182 (5.50%)	22 (1.40%)	160 (9.20%)	<0.001
Two.vessels	803 (24.3%)	372 (23.7%)	431 (24.8%)	0.516
Three.vessels	2273 (68.7%)	1157 (73.8%)	1116 (64.1%)	<0.001
Main.stem	1061 (34.6%)	532 (36.6%)	529 (32.8%)	0.033
Pulmonary hypertension	185 (7.91%)	75 (6.03%)	110 (10.0%)	<0.001
Shock	48 (1.61%)	12 (0.83%)	36 (2.33%)	0.002
Elective	2322 (69.0%)	1106 (70.0%)	1216 (68.1%)	0.267
Urgent	910 (27.0%)	426 (26.9%)	484 (27.1%)	0.943
Emergent	118 (3.51%)	47 (2.97%)	71 (3.98%)	0.137
Salvage	16 (0.48%)	2 (0.13%)	14 (0.78%)	0.012
Ventilated	39 (1.30%)	15 (1.04%)	24 (1.55%)	0.293
On inotropic support	63 (2.11%)	19 (1.32%)	44 (2.83%)	0.006
Critical state	112 (8.19%)	46 (7.20%)	66 (9.07%)	0.247
CPB:				<0.001
Conversion from off-pump	13 (0.39%)	6 (0.38%)	7 (0.39%)	
ONPUMP	2516 (74.6%)	1114 (70.3%)	1402 (78.4%)	
OPCAB	845 (25.0%)	465 (29.3%)	380 (21.2%)	

The data are expressed as numbers (%), or mean (SD)

Table 4. Preoperative characteristics of the patients and graft distribution in the TAR-group versus non-TAR group

	No TAR N=1932	TAR N=1056	p-value
Gender:			0.694
F	364 (18.8%)	192 (18.2%)	
M	1568 (81.2%)	864 (81.8%)	
Age	69.9 (9.31)	64.8 (9.71)	<0.001
Myocardial infarction	595 (34.1%)	226 (25.1%)	<0.001
PCI	340 (19.3%)	226 (25.0%)	0.001
Diabetes.insulin	207 (10.9%)	80 (7.69%)	0.007
Diabetes.oral	416 (21.8%)	172 (16.5%)	0.001
Dialysis	11 (2.05%)	12 (2.26%)	0.982
Creat in mg%	1.08 (0.54)	1.03 (0.55)	0.045
COPD	275 (14.7%)	107 (10.8%)	0.004
Arteriopathy	396 (22.1%)	163 (17.6%)	0.007
CVA	181 (12.2%)	64 (8.53%)	0.012
Poor mobility	0.06 (0.23)	0.03 (0.18)	0.015
BMI	27.8 (4.41)	27.6 (4.31)	0.141
Left.IMA	1825 (94.5%)	1014 (96.0%)	0.074
Right.IMA	539 (27.9%)	764 (72.3%)	<0.001
BIMA	525 (27.2%)	756 (71.6%)	<0.001
RA	5 (0.26%)	44 (4.17%)	<0.001
RGEA	0 (0.00%)	6 (0.57%)	0.002
nr.arterial.anastomoses	1.75 (0.86)	2.69 (1.17)	<0.001
nr.venous.anastomoses	1.82 (0.92)	0.00 (0.00)	0.000

The data are expressed as numbers (%), or mean (SD)

Table 5. Subgroup analysis in function of diabetes type

	Diet control N=119	Insulin N=328	No N=2186	Oral therapy N=685
Left.IMA	118 (99.2%)	307 (93.6%)	2077 (95.0%)	654 (95.5%)
Right.IMA	77 (64.7%)[1,2,3]	122 (37.2%)[4,5]	1098 (50.2%)[6]	305 (44.5%)
BIMA	77 (64.7%)[1,2,3]	121 (36.9%)[4,5]	1078 (49.3%)[6]	300 (43.8%)
TAR	8 (12.9%)[1,2,3]	80 (27.9%)[4]	780 (38.8%)[6]	172 (29.3%)
RA	3 (2.52%)	4 (1.22%)	37 (1.69%)	8 (1.17%)
RGEA	0 (0.00%)	0 (0.00%)	6 (0.27%)	0 (0.00%)
n.art.anast	2.78 (1.39)[1]	2.07 (1.12)	2.30 (2.87)	2.21 (1.39)
n.venous.anast	1.50 (1.00)[2]	1.31 (1.08)[4]	1.12 (1.16)	1.25 (1.08)

The data are expressed as numbers (%), or mean (SD)

[1]= p<0.05 Diet vs Insulin
[2] = p<0.05 Diet vs No Diabetes
[3] = p<0.05 Diet vs Oral therapy
[4] = p<0.05 Insulin vs No Diabetes
[5] = p<0.05 Insulin vs Oral therapy
[6] = p<0.05 No Diabetes vs Oral therapy

Table 6. Subgroup analysis in function of age

	<60 y N=747	60-70 y N=1197	>70 y N=1549
Left.IMA	670 (89.7%)	1099 (91.8%)	1431(92.4%)
Right.IMA	453 (60.6%) [2]	681 (56.9%) [3]	481 (31.1%)
BIMA	449 (60.1%) [2]	671 (56.1%) [3]	469 (30.3%)
TAR	320 (51.1%) [1, 2]	399 (40.0%) [3]	337 (24.7%)
RA	19 (2.54%)	15 (1.25%)	19 (1.23%)
RGEA	4 (0.54%) [2]	2 (0.17%)	0 (0.00%)
n.art.anast	2.60 (1.39) [2]	2.42 (1.34) [3]	1.99 (3.31)
n.venous.anast	0.82 (1.09) [1, 2]	1.02 (1.10) [3]	1.45 (1.13)

The data are expressed as numbers (%), or mean (SD)

[1]= $p<0.05$ <60y vs 60y-70y
[2] = $p<0.05$ <60y vs >70y
[3] = $p<0.05$ 60y-70y vs >70y

Table 7. Subgroup analysis in function of BMI

	<30 N=2398	30-35 N=753	>35 N=211
Left.IMA	2268 (94.6%)	717 (95.2%)	198 (93.8%)
Right.IMA	1141 (47.6%)	372 (49.4%)	90 (42.7%)
BIMA	1120 (46.7%)	369 (49.0%)	89 (42.2%)
TAR	775 (36.1%)	211 (32.7%)	61 (33.9%)
RA	42 (1.75%)	9 (1.20%)	2 (0.95%)
RGEA	6 (0.25%)	0 (0.00%)	0 (0.00%)
nr.arterial anast.	2.26 (2.74)	2.30 (1.56)	2.16 (1.28)
nr.venous.anast	1.17 (1.15)	1.18 (1.12)	1.19 (1.07)

The data are expressed as numbers (%), or mean (SD)

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