The Unclampable Ascending Aorta in Coronary Artery Bypass Patients

A Surgical Challenge of Increasing Frequency

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Background—The unclampable ascending aorta (UAA) is a condition increasingly encountered during CABG procedures. We report our experience with CABG patients with UAA and place particular emphasis on the preoperative diagnosis and surgical management.

Methods and Results—UAA was diagnosed in 211 of 4812 consecutive CABG patients (4.3%). On the basis of the chest radiograph, echocardiogram, and coronary angiograph, a preoperative diagnosis was achieved in only 58 patients (27.4%). An age of >70 years, diabetes, smoking, unstable angina, diffuse coronaropathy, and peripheral vasculopathy were all predictors of UAA. Patients were treated with hypothermic ventricular fibrillation (no-touch technique n=129) or beating heart revascularization (no-pump technique n=82) depending on the possibility of founding an arterial cannulation site. The overall in-hospital mortality rate was 2.8% (6 of 211) with no differences between the 2 surgical strategies. The no-touch technique was associated with a greater incidence of neurological complications (stroke and transient ischemic attack), renal insufficiency, and stay in the intensive care unit and hospital. However, at midterm follow-up, more patients of the no-pump group had ischemia recurrence.

Conclusions—A preoperative diagnosis of UAA is achievable only in a minority of patients, which highlights the necessity revising the current diagnostic protocols. The use of the no-touch technique is associated with an high perioperative risk but a superior possibility of complete revascularization, whereas adoption of the no-pump strategy ensures a smoother postoperative course at the expense of an higher incidence of ischemia recurrence. **(*Circulation*. 2000;102:1497-1502.)**

Key Words: aorta ■ atherosclerosis ■ calcium ■ surgery

Diffuse, nearly total circumferential atherosclerotic involvement of the entire ascending aorta that precludes aortic cross-clamping is a challenging situation with major surgical implications.

As the mean age and the severity of the cardiac surgical population grow, this condition is likely to be increasingly encountered, and cardiologists and cardiac surgeons should recognize its growing importance to increase the possibility of preoperative diagnosis and to optimize the therapeutic approach.

In the present report, we review our experience in the treatment of CABG patients with unclampable ascending aorta (UAA) and place particular emphasis on the preoperative diagnosis and surgical management.

Methods

According to a protocol described in detail elsewhere,[1] all patients referred for coronary surgery at our institution undergo preoperative and intraoperative evaluations of the status of the ascending aorta and the carotid arteries.

For the assessment of the ascending aorta, the preoperative chest radiograph and coronary angiograph are carefully evaluated in search of aortic calcifications. Moreover, intraoperative aortic palpation is routinely performed according to the method described by Mills and Everson[2]: after systemic heparinization, a 40- to 50-mm Hg drop in systemic pressure is induced and the aorta is gently palpated. The degree of aortic disease is then graded according to the criteria described by these authors (Table 1). When moderate atherosclerosis is suspected, echographic examination of the aorta is performed, whereas in cases of severe disease, the diagnosis of UAA is usually based on the judgment of the operating surgeon; echographic confirmation is not requested on a routine basis.

In the present study, we limit our analysis to patients with UAA who correspond to the most severe degree of Mills and Everson classification and take into consideration all isolated CABG procedures performed at our institution from January 1993 to September 1999. Patients with concomitant disease of the aorta and the internal carotid arteries were excluded from the data analysis.

Overall, 4812 patients were screened, and in 211 patients (4.3%), a diagnosis of UAA was made. There was an evident annual increase of UAA cases during the study period (Figure 1).

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TABLE 1. Mills and Everson Criteria for Grading Ascending Aorta Atherosclerosis

Degree of Ascending Aorta Disease	Definition
Absent	...
Mild	Small diseased areas on the aorta that could easily be avoided with the aortic cannula and bypass grafts
Moderate	Disease sufficiently extensive to cause concern for possible embolization, yet adequate soft, disease-free areas could be found for cannulation or placement of bypass grafts
Severe	Clearly significant circumferential disease that would necessitate aortic cannulation, aortic cross-clamping, and placement of bypass grafts into diseased ascending aorta

See Mills and Everson.[12]

Surgical Strategy

The surgical technique used was based on the possibility or not of finding an alternative cannulation site. In fact, when the diagnosis of UAA was made, the aortic arch was carefully inspected in search of a disease-free area for placement of the arterial cannula. If arch cannulation was judged impossible, the possibility of femoral artery cannulation was evaluated.

When an arterial cannulation site could be found, we adopted the no-touch technique described by Mills and Everson[2] and Suma.[3] In this instance, hypothermic cardiopulmonary bypass (CPB) was established between the right atrium and the aortic arch (n=81) or the common femoral artery (n=48), and a left ventricle aspiration line was introduced through the right superior pulmonary vein. Aortic cross-clamping and cardioplegia delivery were avoided, and ventricular fibrillation was induced electrically. The target vessels were occluded at the level of the anastomotic site with 5-0 Prolene (Ethicon) or silicone elastomer stitches passed around the artery, and pedicled arterial grafts were mostly used. In 23 patients, myocardial revascularization had to be completed with a saphenous vein proximally anastomosed to an epiaortic branch.

If both the aortic arch and the 2 femoral arteries appeared to be too diseased for cannulation (n=82), the operation was performed without the use of CPB, according to the technique described by Buffolo et al.[4] In these cases, all-arterial revascularization was performed with the in situ internal thoracic and gastroepiploic arteries, and the radial artery was proximally anastomosed to an internal thoracic artery graft at Y. In 10 patients, an integrated approach (surgical grafting of the left anterior descending coronary artery and subsequent percutaneous angioplasty of the other target vessels) had to be used due to the technical impossibility of using >1 arterial graft.[5]

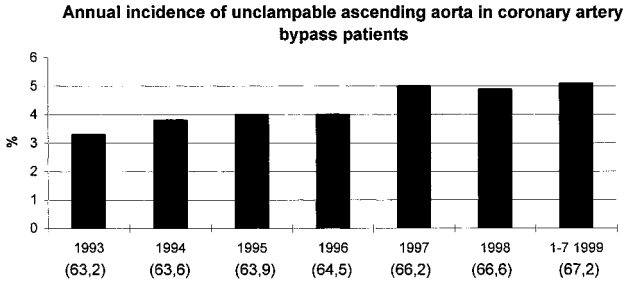

Figure 1. Parallel progressive increase in mean age and incidence of UAA among CABG patients at our institution (value in parentheses refers to mean age of all patients who underwent CABG in that year).

Definitions

For the purpose of the present report, the following definitions were used. "Incomplete revascularization" was defined as the impossibility of grafting ≥1 coronary artery of ≥1.5 mm in diameter with a stenosis of ≥50%. "Peripheral vasculopathy" was defined as a previous vascular surgical procedure (either carotid or aortic or of the lower limbs), a history of previous cerebrovascular event, or clinical or instrumental evidence of vascular insufficiency of any district (carotid, aortic, or the lower limbs). "Postoperative myocardial infarction" was diagnosed on the basis of echocardiographic evidence of regional hypokinesia, MB fraction of >4% of the total hematic level of creatine kinase concentration, and the appearance of new Q waves on the ECG. "Renal insufficiency" was defined as a postoperative increase in the serum creatinine level of ≥3 mg/dL with respect to the preoperative level. "Intraoperative stroke" was defined as a new focal neurological deficit or coma associated with computed tomography demonstration of a recent ischemic cerebral lesion that became evident at the moment of awakening of the patient from the anesthesia and that lasted >24 hours. "Intraoperative transient ischemic attack" (TIA) was defined as a new focal neurological deficit associated with a normal brain scan that became evident at the moment of awakening of the patient from the anesthesia and that lasted <24 hours.

Follow-Up

All patients regularly underwent a clinical examination at our institution 1 and 6 months after surgery and then every year thereafter. A stress myocardial scintigraphy was obtained in all patients 6 months after surgery and every year thereafter. In case of clinical or instrumental suspicion of residual myocardial ischemia or angina recurrence, repeat angiography was always proposed to the patient.

Statistical Analysis

Data are expressed as mean±1 SD. For statistical analysis, qualitative data were compared by the χ^2 test with Bonferroni's correction. Parametric quantitative data were compared by 2-way ANOVA; for a P level of ≤0.05, between-group comparisons were carried out by the unpaired Student's t test with Bonferroni's correction. Nonparametric quantitative data were compared by Friedman's test; for a P level of ≤0.05, between-group comparisons groups were carried out by the test Mann-Whitney U test with Bonferroni's correction. A value of P≤0.05 was considered statistically significant.

Results

Diagnostic Features

The main clinical and angiographic features of the 211 patients are summarized in Table 2.

In an attempt to identify the preoperative variables potentially predictive of UAA, we compared these characteristics with those of 500 randomly selected isolated CABG patients who underwent surgery during the same time period and with a normal ascending aorta (Table 2). This comparison showed that an age of >70 years, diabetes, smoking history, hypertension, unstable angina, 3-vessel or left main disease, and peripheral vasculopathy were all significantly more frequent among UAA patients.

Ascending aorta calcifications were noted on the preoperative chest radiograph, coronary angiograph, or both in 136 of the 211 patients (64.4%). The correlation between the 2 diagnostic modalities was high: in 105 patients, both images showed aortic calcification (77.2%), whereas the aortic pathology was evident only on the radiograph in 14 patients and only on the angiograph in 17 patients (10.2% and 12.5%, respectively). However, it is noteworthy that in less than half

TABLE 2. Comparison Between the Preoperative Characteristics of Patients With and Without UAA

	Patients With UAA	Control Subjects	*P*
No. of patients	211	500	...
Age >70 y, n	163	123	<0.001
M/F, n	155/60	393/107	0.07
Cardiac risk factors, n			
Diabetes	99	86	<0.001
Smoking	152	281	<0.001
Dyslipidemia	102	211	0.15
Hypertension	101	193	0.02
Unstable angina, n	72	64	<0.001
Previous acute myocardial infarction, n	131	296	0.52
3-Vessel disease, n	149	238	<0.001
Left main disease, n	41	63	0.02
Peripheral vasculopathy, n	59	48	<0.001
Overall neurological complications, n	12	7	0.004
TIA	8	5	0.03
Stroke	4	2	0.12

of these 136 patients (58 of 136, or 42.6%), the roentgenographic calcifications were so diffuse that they suggested the possibility of an UAA (Figure 2), whereas in the remaining patients, they appeared isolated and focal and did not elicit the suspicion of a severe aortic pathology.

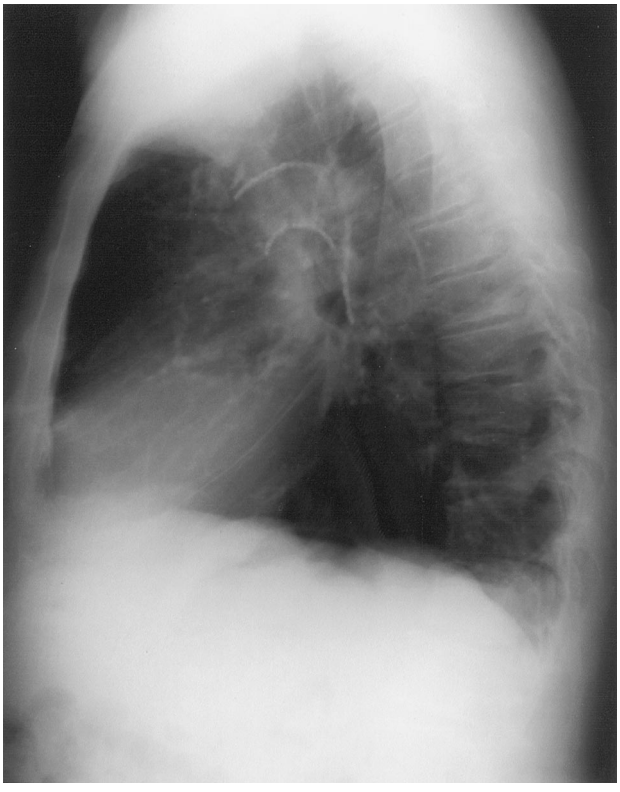

Figure 2. Preoperative lateral chest radiograph of a patient with UAA. Subtotal atherosclerotic calcific involvement of ascending aorta and arch is evident.

TABLE 3. Operative Data With Relation to the Surgical Strategy

	No-Touch Group	No-Pump Group	*P*
CPB time, min	55±18	...	...
Bypass/patient, n	2.5±0.6	1.8±0.3	<0.01
Incomplete revascularization, n	12	25	<0.01

On this basis, a preoperative diagnosis of UAA was achieved in only fewer than one third of all of the patients (58 of 211, or 27.4%).

To verify the diagnostic role of echocardiography, the preoperative transthoracic echocardiograms of the patients who underwent this examination at our institution (n=53) were reviewed retrospectively and independently by 2 expert echocardiographers. This review showed that echographic evidence of aortic calcification was present in 38 of the 53 patients (71.6%). A comparison of these results with the report of the cardiologist who performed the examination showed that in only 9 of these patients (9 of 38, or 23.6%), the echocardiographer preoperatively suggested the possibility of an UAA.

Finally, as stated earlier, intraoperative transesophageal echocardiography was used only in 95 patients (45.0%), and in all instances, the echographic imaging confirmed the surgeon's clinical diagnosis of UAA.

Operative Data

Operative data are reported in Table 3. The mean number of bypasses per patient and the incidence of complete revascularization were both significantly superior in patients treated with the no-touch technique (bypass per patient 2.5±0.6 versus 1.8±0.3, incomplete revascularization 12 of 129 versus 25 of 82; $P<0.001$ for both). However, it should be noted that in 10 patients in whom surgery was performed on the beating heart, surgical revascularization was completed with percutaneous dilatation of the ungrafted coronary vessels, thus reducing the number of no-pump patients incompletely revascularized to 15, a figure not statistically different from that for the no-touch technique ($P=0.09$).

Mortality and Morbidity Rates

The overall mortality rate was 2.8% (6 of 211; see Table 4); 4 deaths occurred in the no-touch group (3.1%) and 2 deaths

TABLE 4. Postoperative Deaths and Complications With Relation to the Surgical Strategy

	No-Touch Group	No-Pump Group	*P*
No. of patients	129	82	...
Operative deaths, n	4	2	0.88
Postoperative complications, n			
Stroke	3	1	0.95
TIA	8	0	0.05
Perioperative acute myocardial infarction	10	3	0.36
Renal insufficiency	15	2	0.03
Revision for bleeding	8	4	0.92

TABLE 5. Incidence of Neurological Complications in the No-Touch Group in Relation to the Site Used for Arterial Cannulation

	Site		
Complication	Aortic Arch (n=81)	Femoral Artery (n=48)	*P*
Stroke, n	2	1	0.64
TIA, n	2	6	0.05
Total, n	4	7	0.11

occurred in the no-pump group (2.4%) ($P=0.88$). In the no-touch series, the causes of death were multiorgan failure (n=2), intestinal infarction (n=1), and myocardial infarction (n=1), whereas in the no-pump series, 2 deaths were due to myocardial infarction and massive pulmonary embolism (n=1 each).

The global incidence of neurological complications (TIA and stroke) was 5.6% (12 of 211), and it was significantly higher in patients treated with the no-touch technique (11 of 129 versus 1 of 82; $P=0.05$). Overt stroke occurred in 3 patients in the no-touch series (2.3%) and in 1 patient in the no-pump series (1.2%; $P=0.95$); TIAs were reported in 8 no-touch patients (6.2%) and in none of the patients in whom surgery was performed on the beating heart ($P=0.05$). Further analysis of the data for the no-touch series revealed that a significantly higher number of TIAs were reported when retrograde perfusion through the femoral artery was used (6 versus 2; $P=0.05$), whereas no difference in the incidence of stroke in relation to the site used for arterial inflow could be detected (see Table 5).

The other major postoperative complications are reported in Table 4. Renal failure occurred significantly more often in the no-touch series (15 of 129 versus 2 of 82; $P=0.03$), but no other significant differences were noted among patients in the 2 groups.

The mean duration of mechanical ventilation and stay in the intensive care unit and hospital were all significantly superior among no-touch patients (29.1±15.2 versus 11.1±7.2 hours, 36.2±12.1 versus 20.9±7.8 hours, and 8.7±4.6 versus 5.2±2.4 days, respectively; $P<0.001$ for all).

Follow-Up

Clinical follow-up was 99.5% complete (204 of 205 patients: 124 of 125 in the no-touch group and 80 of 80 in the no-pump group). The mean follow-up time was 29±7 months for the no-touch patients and 31±9 months for the no-pump patients ($P=0.07$). During this period, there was 5 deaths: 3 among no-touch patients (sudden death in 1 patients and cancer in 2 patients) and 2 among no-pump patients (rupture of aortic aneurysm in 1 patient and stroke in 1 patient).

For the surviving patients, the rate of clinical or instrumental incidence of angina recurrence was 6.0% (12 of 199). This incidence was 1.6% among patients in the no-touch group (2 of 121) and 12.6% among patients in the no-pump group (10 of 78) ($P=0.003$). The 2 recurrences in the no-touch group and 9 of the 10 recurrences in the no-pump group occurred in patients in whom an incomplete revascularization had to be performed. None of the 10 patients in the no-pump group who were treated with the integrated surgery-plus-percutaneous approach had ischemia recurrence during the follow-up period.

Discussion

UAA Incidence, Risk Factors, and Diagnosis

The subtotal atherosclerotic involvement of the ascending aorta presents a formidable technical challenge in patients undergoing CABG procedures and requires a complete redefinition of the operative strategy. In fact, in this instance, the avoidance of aortic manipulation becomes the most important priority, and the all-surgery strategy must be redesigned according to this principle. In this scenario, the reduction in the embolic risk and the need to perform a revascularization as complete as possible often are 2 conflicting issues, and the surgeon is faced with the dilemma of privileging the one at the expense of the other.

Despite the relative abundance of autoptic or echocardiographic study on aortic atherosclerosis present in the literature, it must be noted that both the pathological and echographic definitions of severe ascending aorta atherosclerosis are less restrictive and not comparable to the surgical one of unclampable aorta, so to date, very little information can be found on the incidence of UAA in the population of patients who undergo CABG procedures.

In their classic study, Mills and Everson[2] reported UAA in 34 of their 1735 patients (2.0%). However, other series had different results. Peigh et al[6] diagnosed UAA in only 6 of 2658 consecutive coronary patients (0.2%), whereas Bar-El et al[7] found an incidence of 4.7% (30 of 632). More recently, Dietl et al[8] found UAA in 18 of 1555 patients who underwent myocardial revascularization (1.1%), which confirms the 1.5% incidence reported by Culliford et al.[9] Finally, an autoptic study performed on hearts from 100 individuals with clinical coronary atherosclerosis described circumferential involvement of the all ascending aorta in 2 patients.[10]

These data and the 4.3% incidence of the present study suggest that UAA should probably be expected in 2% to 5% of patients referred for myocardial revascularization procedures.

Due to its potential to radically modify the surgical strategy, the preoperative recognition of UAA is of major importance. Unfortunately, no reliable diagnostic criteria have been established to date, and the diagnosis of UAA remains an intraoperative surprise in the great majority of cases (as confirmed by our series in which fewer than one third of patients were recognized preoperatively).

Although no systematic investigation on this issue has been performed, in the Mills and Everson series,[2] disease of the carotid arteries or the abdominal aorta and stenosis of the left main coronary artery were all significantly associated with UAA, and many other authors reported that advanced age was one of the most common features of UAA patients.[7,11]

In addition, it is known from echocardiographic studies that advanced age, hypertension, diabetes, dyslipidemia, peripheral vasculopathy, diabetes, and stenosis of the left main trunk are significant predictors of aortic atheromatous disease,[12–14] and it seems conceivable that their predictive value

should also be valid (at least in part) for UAA. The results of the present investigation give further credence to this hypothesis in that age of >70 years, hypertension, diabetes, smoking history, severe coronary disease, and peripheral vasculopathy are all significantly associated with UAA (see Table 2).

With this view, the growing age and severity and incidence of comorbidities of patients referred for coronary operations is the most likely explanation for the annual increase in UAA incidence observed in the present study (see Figure 1); it is plausible that this trend will continue in the near future and that UAA will become a condition that is increasingly encountered.

The presence of aortic calcification on the preoperative radiograph or coronary angiograph has traditionally been regarded as a marker for the presence of an atherosclerotic aorta.[15] However, several reports have already underscored the poor specificity of this sign for the diagnosis of severe ascending aorta atherosclerosis, showing that if a positive chest radiograph has an acceptable predictive value, a negative one does not exclude the presence of aortic plaques.[8,16–19] In fact, in our investigation, radiological evidence of calcification was present in ≈65% of the UAA patients, but in fewer than one third of cases was this finding so diffuse as to suggest the correct diagnosis (Figure 2).

A more accurate diagnostic method seems to be the preoperative echocardiographic examination of the ascending aorta. Because the routine adoption of transesophageal echocardiography is limited by obvious logistic and economic considerations, even transthoracic echocardiography can be useful for this purpose. This diagnostic modality can be used to clearly visualize calcified aortic plaques (although it is often unable to provide detailed images of the all aortic walls) and can provide a useful screening tool for patients considered at risk for the presence of UAA (eventually followed by transesophageal imaging in suspected cases); of our 53 patients in whom transthoracic preoperative echocardiography was available, 38 had evidence of aortic calcification (71.6%).

However, the poor echocardiographic recognition of UAA in our series (with only 9 of the 38 cases diagnosed preoperatively) suggests that echocardiographers often pay little attention to the degree of aortic atherosclerosis in cardiac surgery patients.

Instead, cardiologists should be aware of the major importance of evaluating the degree of atherosclerosis of the ascending aorta in patients referred for cardiac operations, and it is plausible that even slight modifications of the habitual preoperative assessment would markedly increase preoperative UAA diagnosis and translate into obvious clinical benefits.

Surgical Management

Several technical alternatives have been described to deal with UAA: ascending aorta graft replacement, aortic endarterectomy, the use of fibrillatory arrest, and hypothermic CPB combined with maximal use of pedicled arterial grafts (no-touch technique) and beating heart revascularization (no-pump technique).

Aortic endarterectomy or graft replacement (both are performed during a period of hypothermic circulatory arrest) have been proposed as the only radical treatment for patients with UAA, because they simultaneously allow the performance of the revascularization procedure and eliminate a possibly dangerous font of systemic emboli.[16,20,21] However, these procedures are highly complex and invasive and carry a considerable operative risk.

The no-pump and no-touch techniques are clearly less aggressive and hazardous and are the strategies most widely adopted to revascularize patients with UAA.

Despite that, to date the relative benefits and limits of these 2 solutions have not been elucidated in detail, and the choice of 1 or the other has been mainly empirical and based on the surgeon experience and preference.

Undoubtedly, the beating-heart technique offers an inferior possibility of complete revascularization; in fact, despite recent reports on its technical feasibility,[22] the no-pump grafting of the lateral branches of the circumflex artery has not yet been definitely standardized and is in fact not feasible in a considerable percentage of cases. On the other hand, the no-touch technique involves the insertion of the arterial cannula into a diseased aorta or the retrograde flow via the femoral artery, both of which are conditions that can predispose to systemic and cerebral emboli and can increase the operative risk[23]; in this regard, it is interesting to note that in our series, retrograde aortic perfusion was a major risk factor for intraoperative TIAs (see Table 5). Because UAA is a marker of diffuse vasculopathy and is usually found in patients with systemic vascular involvement, the advantage of avoiding CPB (and minimizing the risk of cerebral, renal, and mesenteric embolization) must then be weighted against that of a complete surgical revascularization.

In the present study, the incidence of stroke was acceptable with both the no-pump and no-touch techniques (2.3% and 1.2%, respectively). However, the global number of neurological complications (TIA and stroke) was significantly higher in the no-touch group (although the statistical significance was reached on the basis of the largely superior incidence of TIAs, Table 4), testifying to the risk of cerebral embolization associated with even minimal degrees of aortic manipulation.

Even though the 2 surgical strategies were comparable in terms of overall mortality and morbidity rates, the no-touch revascularization was associated with a superior incidence of renal failure and a longer stay in the intensive care unit and the hospital, whereas, as expected, the no-pump technique offered an inferior possibility of revascularization (testified to by the low degree of complete grafting). However, the combination of the beating heart revascularization and percutaneous cardiologic interventions (the "integrated approach") overcame this last limitation, and although at midterm follow-up patients who underwent surgery without CPB had a superior incidence of residual ischemia, this finding did not apply to patients treated with the integrated strategy who in fact did not experience angina recurrence. In addition, in the great majority of cases, postoperative myocardial ischemia was detected only instrumentally and marginally affected the quality of life of the patients who, in most

instances, were polyatherosclerotic, were affected by associated systemic pathologies, and had limited functional capacities.

It seems then that when complete revascularization can be achieved through no-pump grafting (alone or in combination with percutaneous interventions), the beating heart technique should be regarded as the first-choice strategy for UAA patients, whereas in the other cases, the choice between the 2 techniques must take into account the relative merits and limits of each strategy and, most importantly, must be individualized to the clinical and angiographic characteristics of each patient.

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