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European Journal of Cardio-thoracic Surgery 18 (2000) 307–312

EUROPEAN JOURNAL OF  
CARDIO-THORACIC  
SURGERY[www.elsevier.com/locate/ejcts](http://www.elsevier.com/locate/ejcts)

# Surgery for acute type a aortic dissection: comparison of techniques<sup>☆</sup>

Urs Niederhäuser<sup>a,\*</sup>, Hannes Rüdiger<sup>a</sup>, Andreas Künzli<sup>a</sup>, Burkhardt Seifert<sup>b</sup>, Jürg Schmidli<sup>a</sup>,  
Paul Vogt<sup>a</sup>, Marko Turina<sup>a</sup>

<sup>a</sup>Clinic for Cardiovascular Surgery, University Hospital Zurich and City Hospital Triemli, Zurich, Switzerland

<sup>b</sup>Institute for Biostatistics, University Hospital Zurich and City Hospital Triemli, Zurich, Switzerland

Received 7 September 1999; received in revised form 7 March 2000; accepted 6 June 2000

## Abstract

**Objective:** In order to determine the optimal surgical strategy for acute ascending aortic dissection, the graft inclusion technique was compared with the open resection technique. **Methods:** Between 1985 and 1995 a consecutive series of 193 patients (77% male, mean age 58 years) had emergency surgery during a mean interval of 13.2 h after onset of symptoms. Graft replacement of the ascending aorta was performed in all patients (supracoronary graft 143/193 = 74%, aortic root replacement 50/193 = 26%, aortic valve replacement 73/193 = 38%, arch replacement 44/193 = 20%) The open resection technique was applied in 93 patients and the inclusion technique in 100 patients with a Cabrol-shunt in 26%. Preoperative risk factors were equally distributed between groups (inclusion technique vs. open technique): left ventricular ejection fraction < 45% (13 vs. 2%, not significant (n.s.)), neurological deficit (31 vs. 25%; n.s.), systolic blood pressure < 90 mmHg (20 vs. 15%, n.s.) pericardial tamponade (25 vs. 9%, n.s.), renal failure (6 vs. 4%; n.s.). **Results:** The overall early mortality was 24%. Following graft inclusion it was 31% compared with 16% in the open technique group ( $P = 0.0154$ ). Postoperative complications (graft inclusion vs. open technique): myocardial infarction (9 vs. 12%, n.s.), low cardiac output (40 vs. 32%, n.s.), reexploration for hemorrhage (23 vs. 25%, n.s.). Survival at 8 years was significantly increased in the open technique group ( $P = 0.0300$ ). Pseudoaneurysm formation occurred in 3% of patients and only after graft inclusion. Freedom from reoperation was 80% at 8 years and did not differ between groups. Graft inclusion was an independent significant predictor of early ( $P = 0.0069$ ; relative risk = 2.3673) and late mortality ( $P = 0.0119$ ; relative risk = 2.0981). **Conclusions:** Surgery of acute ascending aortic dissection still carries a considerable early mortality whereas the late outcome is satisfactory. The open resection technique is the method of choice showing superior early and late results and avoiding pseudoaneurysm formation. The inclusion technique may be indicated in situations with increased risk of bleeding. A consequent decompression of the perigraft-space could reduce the rate of pseudoaneurysms. © 2000 Elsevier Science B.V. All rights reserved.

**Keywords:** Aortic dissection; Ascending aorta; Graft replacement; Surgical technique

## 1. Introduction

Acute ascending aortic dissection carries a high early mortality mainly caused by proximal aortic rupture with fatal pericardial tamponade. As treatment modality of choice undelayed surgery has evolved [1–5]. In the acute phase of the disease the aortic tissue, however, is friable because of the dissection process and the underlying aortic pathology making surgery technically difficult. Organ ischemia caused by malperfusion of dissected aortic branches and

coagulation disorders add to the high early risk. The graft inclusion technique, published by Bentall and De Bono [6] for aortic root replacement, was used at a time when bleeding was a major problem. With the development of new surgical materials and techniques (perfusion techniques, organ protection, tissue glue, zero-porosity grafts) an open graft-implantation technique [7] could be adopted. It allowed the resection of pathologic aorta and a more anatomic graft interposition.

It was the aim of this study to determine the early and late results of surgery in acute ascending aortic dissection. Special interest was focused on the comparison of graft inclusion with the open resection technique.

## 2. Material and methods

Between 1985 and 1995 emergency surgery for acute type

<sup>☆</sup> Presented at the 13th Annual Meeting of the European Association for Cardio-thoracic Surgery, Glasgow, Scotland, UK, September 5–8, 1999.

\* Corresponding author. Clinic for Cardiovascular Surgery, Hospital Beau-Site, Schänzlihalde 11, CH-3000 Bern 25, Switzerland. Tel.: +41-31-318-7766 (office); +41-31-335-3333 (hospital); fax: +41-31-318-7768.

E-mail address: [niederhaeuser.herzcenter@swissonline.ch](mailto:niederhaeuser.herzcenter@swissonline.ch) (U. Niederhäuser).

A aortic dissection (Stanford classification [8]) was performed in 193 patients at the University Hospital and the City Hospital Triemli, Zurich, Switzerland. In all patients the operation was performed during the first 24 h after onset of dissection symptoms with a mean interval of  $13 \pm 7$  h. Clinical data were obtained by retrospective review of hospital records. Post-operative follow-up data contain periodical cardiological reports and questionnaires. The mean follow-up in early survivors was  $51.0 \pm 32.0$  months.

Demographic, preoperative and intraoperative data are listed in Table 1.

Previous cardiac surgery was performed in 15 of 193 patients (7.7%): aortic valve replacement (AVR) in eight patients (3.9%); coronary artery bypass graft (CABG) in four patients (1.9%); atrial septal defect, arch replacement and mitral valve replacement in one patient each (0.5%).

### 2.1. Operation

A standard median sternotomy was performed and total cardiopulmonary bypass was instituted by cannulation of the femoral artery and the right atrium. The application of cold blood cardioplegia with high potassium content was antegrade in 106 patients and retrograde in 87 patients using a transatrial cannulation of the sinus venosus.

Graft inclusion was performed according to the technique described by Bentall [6] for aortic root replacement. The ascending aorta was not resected and was incised longitudinally. The tubular graft was anastomosed inside and into

the true lumen of the aorta. In cases of severe destruction the dissected intimal layer of the aortic wall was 'endarterectomized' and inclusion was performed only with the outer layer of the false channel. For aortic root replacement the coronary ostia were anastomosed to the graft in a side-to-side fashion [6]. Finally, wrapping of the graft was performed using the remnants of the aortic wall. In 26 patients of the inclusion group (26%) the perigraft space was decompressed using a Cabrol shunt [9] to the right atrium.

With the open technique the replaced and diseased aortic segment was resected and a graft was interposed using an end-to-end anastomosis. Gelatine-resorcinol-glutaraldehyde/formaldehyde glue (Trigone GmbH, Mönchengladbach, Germany) [10] was used to seal the dissected aortic wall. With this technique aortic root reconstruction and valve competence could be achieved [11] and the aortic wall could be reinforced at the level of the graft anastomoses.

During the first half of the study period (1985–1990), 50 patients were operated on using the inclusion technique and 20 patients using the open technique ( $P = 0.00004$ ).

In the inclusion group mean extracorporeal circulation (ECC) time was  $137.5 \pm 72.2$  min, aortic cross-clamp time was  $70.5 \pm 8.5$  min and circulatory arrest time was  $17.7 \pm 8.7$  min. In the open group the corresponding times were  $131.5 \pm 71.1$  min ( $P = 0.507$ ),  $71.6 \pm 30.7$  min ( $P = 0.868$ ) and  $18.3 \pm 9.3$  min ( $P = 0.003$ ). Hypothermic circulatory arrest was used for interventions

Table 1  
Demographic, preoperative and intraoperative data<sup>a</sup>

Parameters	Inclusion technique	%	Open technique	%	P
No. of patients	100	48.3	93	44.9	0.554
Age (years)	$58 \pm 11$		$57 \pm 11$		0.155
Male gender	72	72.0	76	81.7	0.111
Pericardial tamponade	25	25.0	8	8.8	0.003
Renal failure	6	6.0	4	4.3	0.595
Temporary neurologic deficit	28	28.0	21	22.6	0.387
Persisting neurologic deficit	3	3.0	2	2.2	0.711
AI severe	13/76 pat.	17.1	7/74 patients	9.4	0.169
LVEF <30%	4/53 pat.	7.5	1/58 patients	1.7	0.140
Previous cardiac surgery	5	5	9	9.7	0.2107
Pulse deficit at one localization	19	19	16	17.2	0.7463
Dissected					
Asc. aorta	19	19.0	16	17.2	0.746
Asc. aorta + arch	15	15.0	17	18.3	0.540
Asc./desc. aorta + arch	66	66.0	59	63.4	0.710
Coronary artery	13	13.0	11	11.8	0.805
Site of intimal tear					
Asc. aorta	73	73	77	82.8	0.1022
Arcus aortae	5	5	6	6.5	0.6638
Distal aorta	9	9	9	9.7	0.8715
Retrograde cardioplegia	31	31	59	63.4	<0.001
Use of tissue glue	22	22	41	44.1	0.001
Use of aprotinine	41	41	71	77.2	<0.001

<sup>a</sup> AI, aortic insufficiency; asc., ascending; desc., descending; LVEF, left ventricular ejection fraction. Echocardiographic data on left ventricular ejection fraction and aortic insufficiency were available only for 150 and 111 patients, respectively.

at the level of the aortic arch and for construction of an open distal anastomosis. It was applied in 44 patients of the inclusion group (44%) and in 63 patients (68%) of the open group ( $P = 0.0009$ ). During rewarming antegrade reperfusion was instituted if there was dissected aorta distal to the graft.

A segment of the ascending aorta was replaced in all patients with a tubular Dacron graft. A supracoronary graft was implanted in 143 of 193 patients (74%). In the inclusion group 66 patients (66%) had supracoronary graft implantation compared with 77 patients (83%) in the open group ( $P = 0.00779$ ). Aortic root replacement with a composite graft was performed in 50 of 193 patients, aortic valve replacement in 73 of 193 patients (38%) and arch replacement in 44 of 193 patients (20%) with a hemiarch procedure in 40 patients.

A simultaneous coronary revascularization procedure was performed in 10 patients (10%) with graft inclusion and in 21 patients (23%) with open graft implantation ( $P = 0.017$ ).

## 2.2. Statistical analyses

The Statistica software package (Stat Soft, Inc., 1993) and SPSS (SPSS Inc., Chicago, IL) were used for statistical analysis. Continuous variables were summarized as mean  $\pm$  standard deviation. Survival and event-free probabilities  $\pm$  standard error were calculated by actuarial analyses [12]. Differences between survival curves were estimated using the log rank test. Predictors for mortality and reoperation were determined by univariate and multivariate analysis. In univariate analysis discrete variables were analyzed by the chi-squared or Fisher's exact test. Continuous variables were analyzed by the Mann–Whitney test. Statistical significance was associated with a  $P$  level of less than 0.05. Selected variables were entered into multivariate analysis by a stepwise logistic regression or by Cox proportional hazard regression to determine independent predictors.

## 3. Results

Early mortality in all 193 patients was 23.8% (46/193). Following graft inclusion early mortality was 31.0% (31/100) compared with 16.1% (15/93) after the open technique ( $P = 0.0154$ ). During the first half of the study period (1985–1990), early mortality was 24.4 vs. 23.4% in the second half ( $P = 0.8644$ ). In the open technique group early mortality was lower during the first half (10.7 vs. 32%,  $P = 0.03985$ ) and during the second half (18.5 vs. 30.9%,  $P = 0.13596$ ) of the study period. Univariate significant predictors for early death were: increasing age ( $P = 0.0032$ ), pericardial tamponade ( $P = 0.0001$ ), preoperative ( $P = 0.0525$ ) and postoperative ( $P = 0.0001$ ) neurologic deficit, inclusion technique ( $P = 0.0154$ ), duration of ECC ( $P < 0.0001$ ) and perioperative myocardial infarction. Independent significant risk factors for early mortality were: the inclusion technique ( $P = 0.0069$ , rela-

tive risk 2.3673) and postoperative neurologic deficit ( $P = 0.0001$ , relative risk 14.3525).

Following open graft implantation, survival was  $77.3 \pm 3.0\%$  after 30 days,  $72.5 \pm 3.2\%$  after 1 year,  $64.5 \pm 3.7\%$  after 5 years and  $61.8 \pm 4.4\%$  after 8 years. For graft inclusion the corresponding figures were  $70.8 \pm 4.6\%$  after 1 month,  $65.6 \pm 4.8\%$  after 1 year,  $59.1 \pm 5.1\%$  after 5 years and  $55.1 \pm 6.1\%$  after 8 years ( $P = 0.02998$ ) (Fig. 1). Complications in the late follow-up did not differ significantly between groups and are depicted in Table 2. Independent significant risk factors for late mortality were: age, ( $P = 0.0010$ , relative risk 1.0465); dissection of the coronary ostia ( $P = 0.0615$ , relative risk 2.1672); previous cardiac surgery ( $P = 0.0517$ , relative risk 2.3141) and inclusion technique ( $P = 0.0119$ , relative risk 2.0981).

During the follow-up period a total of 21 patients had to be reoperated after a mean interval of 26.2 months. In 13 of 21 patients the reintervention took place at the level of the proximal aorta. The following reoperations were performed (inclusion vs. open technique). Aortic valve replacement was done in three patients for an insufficient and primarily reconstructed valve (1.0 vs. 2.2% ( $P = 0.9495$ )). For the same indication with additional aneurysm of the ascending aorta, valve replacement and supracoronary graft implantation was performed in four patients (1.5 vs. 1.6% ( $P = 0.5095$ )) and composite graft replacement of the aortic root in six patients (2.0 vs. 4.3% ( $P = 0.6133$ )). Graft replacement of the thoracic and abdominal aorta for aneurysmatic dilatation was necessary in five patients (3.0 vs. 2.2% ( $P = 0.9345$ )). For ischemic complications vascular surgery on aortic branches had to be performed in three patients (3.0 vs. 0% ( $P = 0.2708$ )).

In three patients reoperation was indicated by a pseudoaneurysm at the anastomotic suture lines. A pseudoaneurysm only occurred after graft inclusion and never in the open technique group. In the open technique group, freedom from reoperation (including only early survivors) was  $98.6 \pm 1.4\%$  after 30 days,  $95.6 \pm 2.0\%$  after 1 year and

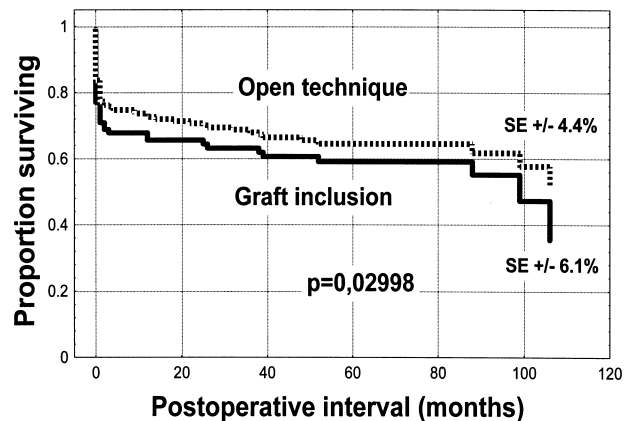


Fig. 1. Actuarial survival comparing the open resection technique with graft inclusion.

Table 2  
Complications during the early and late postoperative period

Complications	Inclusion technique	%	Open technique	%	P
<i>Early</i>					
Perioperative myocardial infarction	9	9	11	11.8	0.520
Low cardiac output	40	40	29	31.5	0.202
Re-exploration (hemorrhage)	23	23	23	25.0	0.746
Neurology transient	8	8	13	14.0	0.165
Neurology permanent	10	10	19	20.4	0.036
Renal failure	8	8	8	8.8	0.880
Intestinal ischemia	2	2	1	1.1	0.527
<i>Late</i>					
Myocardial infarction	1/52 patients	2	1/57 patients	2	0.5164
Hemorrhage	0		0		
Embolism	3/52 patients	6	1/57 patients	2	0.5462
Endocarditis	0		0		
Stroke	1/52 patients	2	7/57 patients	12	0.5164

76.1 ± 7.2% after 5 years. In the graft inclusion group the corresponding figures were 98.6 ± 1.4% after 30 days, 94.0 ± 2.9% after 1 year and 83.3 ± 5.3% after 5 years ( $P = 0.3293$ ). (Fig. 2).

Late complications are listed in Table 2. At the end of the follow-up the mean functional NYHA (New York Heart Association) class was 1.73 ± 0.72 after graft inclusion and 1.95 ± 0.82 in the open technique group ( $P = 0.1501$ ).

#### 4. Discussion

In acute dissection of the ascending aorta, undelayed surgery is the treatment method of choice. In the acute phase of the disease the surgical intervention is technically difficult and demanding. Despite diagnostic and therapeutic improvements over the last decades mortality remained considerably high and was 22.6% in our present series. Similar mortality rates between 21 and 26% are documented by other authors [13–16]. In our experience mortality did not change substantially over the years and Fann from the Stanford group [15] even noted a slight increase in mortality

over the last decade. We can only speculate about the reason for this tendency and we think that faster and accurate echocardiographic diagnosis, prompt patient referral and more efficient preoperative treatment has allowed more high-risk patients to come to operation.

The inclusion technique was described by Bentall and de Bono [6] for aortic root replacement with a composite graft. It was introduced at a time when bleeding problems and leaking graft material was a major surgical concern. Complete graft inclusion with the remaining aorta was a successful method to control bleeding. With the accumulation of blood in the perigraft space, however, anastomotic suture lines could get under tension. This is thought to be a possible mechanism for the development of pseudoaneurysms at these localizations. With the development of new techniques and materials (zero porosity grafts, tissue glue, teflon felt as buttress for anastomotic sutures, aprotinin) an open technique for graft implantation was possible with resection of the replaced, pathologic aortic segment. This technique allowed a better exposition and visibility of pertinent anatomic structures, a more anatomic reconstruction and improved surgical access for the control of hemostasis.

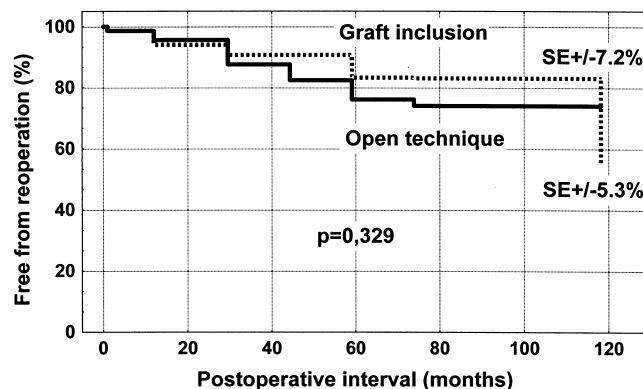


Fig. 2. Reoperation-free survival, comparing the open technique with graft inclusion. Early mortality excluded.

In the present study the open technique was applied in 93 patients and the inclusion technique in 100 patients. Graft inclusion had a significantly increased ( $P = 0.01549$ ) early mortality of 31% compared with a 16.1% mortality of the open technique. This is also true for the early half of the study period whereas during the late period this difference was no longer significant. Graft inclusion was, moreover, an independent significant risk factor for early and late death with a more than twofold risk. Survival after open graft implantation was also significantly better ( $P = 0.02998$ ). Due to the retrospective analysis of our data the two treatment groups were not comparable in all relevant preoperative findings and examinations. Cardiac tamponade, a univariate risk factor for early mortality, was significantly more frequent in the open technique group. Despite this negative finding early survival remained significantly increased in this subgroup of patients. On the contrary, left ventricular dysfunction and severe valve regurgitation were more frequent in the inclusion technique group. Despite lacking statistical significance they may have negatively influenced the early results of this treatment group. In a published series of 348 patients with composite graft replacement of the aortic root, Svensson [17] also compared both implantation techniques. Acute aortic dissection was only present in 34 patients (9.8%) of his series, which showed equal early mortality rates of 9% but improved survival after 3 years for the open technique. The survival difference was not statistically significant (81 vs. 79%,  $P = 0.280$ ).

In our series the rate of reexploration for hemorrhage was 24% and almost similar in both groups. Kouchoukos [7] has published a series of 168 patients with composite graft replacement of the aortic root. Acute aortic dissection was present only in 17 patients of this study. The open resection technique had a significantly lower rate of rethoracotomies (2 vs. 13.3%,  $P = 0.024$ ). The rates of perioperative myocardial infarction and of low cardiac output were similar in both technical groups, a finding published also by other authors [17]. Persistent postoperative neurologic deficits were significantly increased in our open group (20 vs. 10%,  $P = 0.036$ ). In a single patient of this group the neurological complication could be directly related to the open technique because of documented embolization of polymerized glue into a cerebral vessel [18]. This complication should be avoidable by surgical technical measures [19]. Transient neurologic deficits showed similar frequencies in both groups. In the report of Svensson [17] neither technique of graft implantation was in univariate or multivariate analysis a risk factor for postoperative neurologic disorders. In contrast, the Cabrol method [9] of coronary ostial implantation was followed by significantly less neurologic complications. This study contained only a small number of acute dissections (9.8%), which were not analyzed separately. Therefore the total risk for neurologic complications was substantially decreased.

During the follow-up period the rates of thromboembo-

lism, endocarditis, hemorrhage, angina pectoris and myocardial infarction were similar in both groups. The stroke rate was significantly increased in the open technique group. At the end of the follow-up there was no significant difference in the mean functional class (dyspnoe NYHA class).

In contrast to survival, the rate of late reoperations was not significantly different in our two groups. Pseudoaneurysms occurred in only three patients with graft inclusion and were completely avoided in the group with the open resection technique. In the study population of Kouchoukos [7] reoperation-free survival was significantly better with the open technique of graft implantation. Following this technique the rate of pseudoaneurysms was 2% compared with 8.6% after graft inclusion ( $P = 0.049$ ). This author therefore advocates the open technique in accordance with Svensson [17] who also documented a significantly decreased rate of reoperations following open graft implantation. The small number of pseudoaneurysms in our inclusion group may be explained by the fact that in case of excessive bleeding we consequently perform a Cabrol shunt [9] to the right atrium, which was the case in 26% of patients with graft inclusion. This shunt decompresses the perigraft space in order to avoid external graft compression or tension on anastomotic suture lines. In the series of Kouchoukos [7] such a decompression of the perigraft space was not performed in any patient with graft inclusion and in the series of Svensson [17] it was performed in only 5% of patients. Because of our superior early and late results we consider the open resection technique as the method of choice. In case of expected excessive bleeding (coagulopathy, reoperation), graft inclusion may be indicated. Decompression of the perigraft space must be performed with a liberal indication and consequent use of the Cabrol shunt technique.

Certain limitations of the present study have to be mentioned. The choice of technique for graft implantation (open/inclusion) was performed in a non-randomized fashion and was at the surgeon's discretion. In addition, materials and methods have changed considerably during the study period (see Table 1). Together with the retrospective evaluation of the clinical data, these factors are responsible for limitations. A randomized and prospective trial could provide more statistical and predictive power.

We conclude that surgery for acute ascending aortic dissection still has a considerable early mortality and morbidity whereas the late outcome is satisfactory. The open resection technique is the method of choice for graft insertion and showed superior early and late results. Open graft implantation allows a more anatomic reconstruction and has not negatively influenced hemostasis. In the long-term follow-up pseudoaneurysms could be completely avoided. The inclusion technique may be indicated in cases of excessive bleeding (coagulopathy, reoperation). With a liberal use of the Cabrol shunt technique the rate of pseudoaneurysms could be markedly reduced.

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## Appendix A. Conference discussion

*Dr G. Luciani (Verona, Italy):* I have a question. It seems to me that if the

inclusion technique were to expose the patient to an incremental risk, this would be in the long term; however, you have shown that these patients do not have an increased risk of reoperation in the distance, and the difference in late mortality seems to be rather small compared with the great difference in early mortality. So my question to you is, are you looking at the same group of patients and at the same time interval, or were these patients operated during two different time periods? So is there a learning curve involved with the operation that may explain the difference in early mortality?

*Dr Niederhäuser:* It was a retrospective and non-randomized study, and the patients were not equally distributed over the time study period. The technique of operation was at the surgeon's discretion. In the second half of the study period the open technique was applied more often. In another trial about acute dissection, including a study period of 12 years, we have seen an increasing number of older patients with more comorbidity and more risk factors. All this may contribute to an inhomogeneous patient population making comparison between technical groups difficult. As you said, there was not a very impressive difference in late mortality but it was statistically significant.

*Dr R. Bonser (Birmingham, UK):* There is one statement that you made in the conclusions, that I think we should draw issue with, and that is the use of the inclusion technique in the patient at high risk of bleeding. All acute aortic dissections, most probably, have a significant coagulopathy. A lot of patients have hyperfibrinogenemia, elevated D-dimers, as a consequence of the dissection process itself. And in fact, you demonstrated that there was more tamponade in the inclusion group, and so I'm not sure how you derived the conclusion that the inclusion technique may be better when there is a high risk of bleeding.

*Dr Niederhäuser:* The inclusion technique combined with a Cabrol shunt to the right atrium is indicated in patients who have coagulation disorders in addition to acute aortic dissection. These disorders may include thrombolytic therapy for suspected myocardial infarction or any preexisting form of coagulopathies.

*Dr T. Mesana (Marseille, France):* I have a short comment and a short question. I think it's hard to talk about pseudoaneurysms without having a routine follow-up of patients, including MRI or whatsoever. So did you enforce this type of follow-up?

*Dr Niederhäuser:* Our patients are followed by a regular protocol including a CT scan at 3 months postoperatively and thereafter at annual intervals. With these measures we cannot detect all pseudoaneurysms but a high rate of them.

*Dr Mesana:* Because most of these pseudoaneurysms are really asymptomatic, they are difficult to assess without a routine follow-up, up to 3 or 5 years. Also, your last comment mentioned that Cabrol shunt may prevent pseudoaneurysm. I didn't see clearly the reason why, in function of your results, you assessed that Cabrol shunt could reduce the rate of pseudoaneurysms. Is it easier to do Cabrol shunt with such fragile adventitia tissue sutured to the atrium? It may be different in the repair of aneurysms and aortic dissections.

*Dr Niederhäuser:* Could you please repeat your second question?

*Dr Mesana:* How did you assess that the Cabrol shunt can reduce the rate of late aneurysm in your population of patients and at the same time you demonstrated that the inclusion technique provided more aneurysm?

*Dr Niederhäuser:* I think the Cabrol shunt has to be performed because we want to decompress the perigraft space in order to reduce tension at the suture lines, which may be responsible for a pseudoaneurysm formation.

*Dr A. Biederman (Warsaw, Poland):* I have two questions for you. Do you still use both techniques currently? Do you still operate on patients with inclusion and open technique or just open technique now? That is the first question. And the second is, maybe I missed, but I don't remember, did you state how many of your patients were type I or type II dissection?

*Dr Niederhäuser:* The open resection technique is standard procedure but in patients with an additional risk of bleeding we perform graft inclusion. All patients in this study had acute type A dissection and about 15% had DeBakey Type II dissection.