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# Acute safety and efficacy of the NeoChord procedure[†]

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## Abstract

**OBJECTIVES**: Transapical off-pump mitral valve repair using the NeoChord device has been proposed to treat degenerative mitral valve regurgitation. This prospective study sought to evaluate acute safety and efficacy of this innovative, minimally invasive, transcatheter mitral valve repair approach.

**METHODS**: Symptomatic patients with severe mitral regurgitation (MR) were selected if they presented a favourable valve anatomy (the presence of leaflet flail/prolapse with consistent overlap of tissue). Early device success was defined as placement of at least two neochordae with residual mitral regurgitation ≤2+ after the procedure. The primary acute safety and efficacy end points were evaluated at 30 days.

**RESULTS**: Between February 2013 and June 2014, in Padua and Vilnius University Hospitals, a total of 62 patients were treated, with a median age of 66 years (IQR 52–76) and a median EuroSCORE I of 1.9% (IQR 0.9–6). Fifty-six patients (88.9%) presented with a posterior leaflet prolapse, 4 (6%) with an anterior leaflet prolapse and 3 (5%) with a combined disease. Early procedural success was achieved in all patients. Two neochordae were implanted in 2 patients (3%), 3 in 20 (32%), 4 in 28 (44%), 5 in 10 (16%), 6 in 2 (3%) and 7 in 1 (2%). At 30 days, major adverse events included only 1 acute myocardial infarction (2%) successfully treated percutaneously and 2 cases of sepsis (3%). Mitral regurgitation at 30 days was absent in 29 patients (46%), Grade 1+ in 16 (25%), Grade 2+ in 10 (16%), Grade 3+ in 7 (11%) and Grade 4+ in 1 (2%). All 8 patients with MR >2+ were successfully reoperated with conventional surgery or NeoChord reintervention.

**CONCLUSIONS**: Initial results with the NeoChord procedure in a small number of patients indicate that transapical off-pump mitral valve repair is feasible and safe. Efficacy is maintained up to the 30-day follow-up with significant clinical benefit for patients.

**Keywords:** Mitral valve • Regurgitation • NeoChord procedure • Mitral valve repair • Off-pump

## INTRODUCTION

Mitral valve (MV) repair surgery is the gold standard treatment of MV prolapse because of its greater postoperative and long-term survival rates and a more physiological left ventricular function preservation than prosthetic valve replacement [1–3]. Chordal replacement with implantation of polytetrafluoroethylene sutures is an established repair technique in open heart surgery with excellent short- and long-term results [4–6]. In striving towards a transapical beating-heart approach, the NeoChord DS 1000 (NeoChord, Inc., Minneapolis, MN, USA) device has been developed to realize minimally invasive MV repair with implantation of neochordae, under transesophageal echocardiographic (TEE) guidance [7]. The transapical off-pump MV intervention with NeoChord implantation (TOP-MINI) has been evaluated in animal studies [8–10], followed by initial clinical investigations [11, 12].

The aim of this paper is to evaluate the safety and efficacy of TOP-MINI in a consecutive cohort of symptomatic patients with severe mitral regurgitation (MR) due to leaflet flail or prolapse, treated in two European centres.

## MATERIALS AND METHODS

### Study design

This observational study was conducted at Padua and Vilnius University Hospitals, from February 2013 to June 2014. All data were prospectively collected in the NeoChord International Independent Registry (NIIR). All patients were candidates for conventional MV repair surgery, according to the current guidelines [1]. Patients were

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considered eligible for NeoChord implantation when severe MR was due to isolated prolapse or flail of the posterior, anterior or both MV leaflets. Exclusion criteria were the presence of active endocarditis or unfavourable MV anatomy (minor leaflet flail/prolapse with a flail gap of <4 mm and functional or ischaemic MR).

All patients underwent 2D transthoracic (TTE) and 3D TEE, coronary catheterization and clinical assessment before the intervention to determine the severity of MR, MV morphology and New York Heart Association (NYHA) functional class. Preoperative baseline echocardiograms were used to determine the suitability for NeoChord implantation, the optimal planned number of neochordae to be deployed and their target location on the prolapsing leaflet. TTE and clinical assessment were re-evaluated at discharge and 30 days after surgery.

All patients were informed on the specific operative risks, clinical results of the NeoChord procedure and alternative surgical procedures. Each patient provided individual '*ad hoc*' written informed consent to undergo NeoChord procedure, pre- and postoperative evaluation according to local ethical indications. TTE and TEE were obtained using commercially available ultrasound diagnostic systems (iE33, Philips Medical Systems, Andover, MA, USA) by experienced investigators. Three cardiac cycles were stored in cine-loop format for off-line analysis. Off-line analysis of echocardiographic examinations was conducted on a commercial workstation (Q lab, 7.1, Philips, Netherlands) by independent expert investigators who were unaware of patients' clinical status and were not involved in NeoChord procedures.

MR severity was graded according to the American Society of Echocardiography guidelines [13].

## Study outcomes

Early procedural success was defined as implantation of at least two neochordae with immediate reduction in MR to less than 2+.

Safety outcomes included perioperative complications, in-hospital and 30-day major and minor adverse events (MAEs). Among perioperative complications, we considered ventricular fibrillation (VF), haemodynamic instability needing extracorporeal membrane oxygenation, surgical revision for bleeding or apex rupture and conversion to conventional surgery for immediate NeoChord failure. As major adverse events we evaluated mortality, stroke, acute myocardial infarction (AMI) and septicaemia (positive blood cultures in patients with fever). Among MAEs, we considered severe pericardial effusion, wound dehiscence, gastrointestinal complications requiring surgery, acute renal failure requiring continuous veno-venous haemofiltration, definitive pace maker (PM) implantation and new onset of permanent atrial fibrillation.

Primary efficacy outcomes were defined as reduction in MR to less than 2+ at the 30-day follow-up, freedom from reoperation for recurrence of severe MR and clinical improvement (NYHA functional class).

## Statistical considerations

Continuous variables are presented as median and interquartile range (25th–75th percentile), and categorical data as absolute frequencies and percentages.

# RESULTS

## Patients' characteristics

Between February 2013 and June 2014, 62 patients underwent 63 TOP-MINI procedures in Padua ($n = 31$ patients and $n = 32$ procedures) and Vilnius University Hospital ($n = 31$ both for patients and procedures), inserted into the NIIR. Patients' baseline characteristics and preoperative echocardiographic parameters are described in Table 1. The median age was 66 years (IQR 52–76) and 42 (67%) patients were male. They presented a low surgical risk with a median EuroSCORE I of 2% (IQR 0.9–6), median EuroSCORE II of 1% (IQR 0.7–2.3) and a median Society of Thoracic Surgeons score of 1% (IQR 0.4–1.7).

All patients suffered from severe symptomatic MR (3+ or 4+ grade) or were under medical treatment. Three patients (5%) were in NYHA Class I, 25 (40%) in NYHA Class II, 31 (49%) in NYHA Class III and 4 (6%) in NYHA Class IV. The majority of the patients ($n = 56$, 89%) presented with a posterior mitral leaflet (PML) prolapse, 4 (6%) with an anterior mitral leaflet (AML) prolapse and only 3 (45%) with a combined disease. Fifty-four patients (856%) had left ventricular (LV) ejection fraction (EF) greater than 55% (median LVEF 60%, IQR 60–60); 55 patients (87%) had normal LV dimensions or mild LV dilatation (end-diastolic volume, EDV, <100 ml/m$^2$, median EDV 74.5 ml/m$^2$, IQR 63–89). Most patients ($n = 44$, 70%) had pulmonary hypertension (systolic pulmonary artery pressure >26 mmHg) and 41 (65%) presented with mild or moderate tricuspid regurgitation.

All patients attended clinical and echocardiographic follow-up examination at discharge and 1 month after the TOP-MINI procedure with the 3-, 6- and 12-month follow-up ongoing.

## Procedural results

Early procedural success was achieved in all patients and a median of four NeoChords (IQR 4–5) were implanted. Two NeoChords were implanted in 2 patients (3%), 3 in 20 cases (32%), 4 in 28 (44.4%), 5 in 10 (16%), 6 in 2 (3%) and 7 in 1 (2%). The median procedure duration (calculated as skin-to-skin) time was 130 min (IQR 117.5–150).

The median duration of stay in the intensive care unit (ICU) after TOP-MINI was 24 h (IQR 24–24). The median duration time of mechanical ventilation support was 3 h (IQR 2–5). The last 7 patients (12%) of the series were extubated in the operating room.

Patients were discharged after a median hospital stay of 8 days (IQR 6–11). Nine patients (14%) were discharged home, whereas 54 patients (86%) were discharged to a cardiac rehabilitation centre. A complete list is given in Table 2.

## Safety outcomes

All patients except 3 (5%) presented with haemodynamic stability during the procedure. No conversion to conventional open MV surgery was necessary. Both intraprocedurally and in the immediate postoperative period, there was no death, stroke, major bleeding, acute renal failure or respiratory failure. Two patients (3%) had sepsis and 3 patients (4.8%) were transfused with more than 2 units of blood. AMI was observed acutely in 1 patient (2%) at the end of the procedure due to the occlusion of an intramural distal diagonal branch followed by severe left main coronary artery

**Table 1:** Patients' baseline characteristics and preoperative echocardiographic parameters

| Variable | *N* = 63 Median (IQR I, III) |
|---|---|
| Age (years) | 66 (52–76) |
| Male gender (*n*) | 42 (67%) |
| Logistic EuroSCORE I (%) | 1.9 (0.9–6) |
| EuroSCORE II (%) | 1 (0.7–2.3) |
| STS score (%) | 0.8 (0.4–1.7) |
| Arterial hypertension | 55 (87%) |
| Chronic obstructive pulmonary disease | 3 (5%) |
| Diabetes mellitus type II | 3 (5%) |
| Associated ischaemic cardiomyopathy | 8 (13%) |
| Reintervention | 3 (5%) |
| Previous coronary artery bypass grafting | 2 (3%) |
| Previous mitral valve repair | 1 (2%) |
| Prior percutaneous coronary intervention | 4 (6%) |
| Prior stroke | 0 |
| Glomerular filtration rate (ml/min) | 83 (64–107) |
| >90 | 27 (43%) |
| 60–89 | 23 (36%) |
| 59–30 | 11 (17%) |
| <29 | 2 (3%) |
| NYHA functional Class | |
| I | 3 (5%) |
| II | 25 (40%) |
| III | 31 (49%) |
| IV | 4 (6%) |
| Mitral regurgitation severity | |
| 3+/4 | 7 (11%) |
| 4+/4 | 56 (89%) |
| Leaflet involvement | |
| Posterior mitral leaflet (PML) | 56 (89%) |
| Anterior mitral leaflet (AML) | 4 (6%) |
| AML and PML | 3 (5%) |
| Mitral valve anatomical types[a] | |
| A | 22 (35%) |
| B | 27 (43%) |
| C | 14 (22%) |
| Tricuspid regurgitation | |
| 0+/4 | 22 (35%) |
| 1+/4 | 33 (52%) |
| 2+/4 | 8 (13%) |
| Left ventricular ejection fraction (%) | 60 (60–65.5) |
| >55 | 54 (86%) |
| 30–55 | 9 (14%) |
| Left ventricular end-diastolic volume (ml/min) | 74.5 (63–89) |
| <70 | 24 (38%) |
| 70–100 | 31 (49%) |
| >100 | 8 (13%) |
| Systolic pulmonary artery pressure (mmHg) | 35 (25–45.5) |
| ≤25 | 19 (30%) |
| 26–35 (mild) | 13 (21%) |
| 36–44 (moderate) | 13 (21%) |
| ≥45 (severe) | 18 (29%) |

[a]Type A: isolated central posterior leaflet (P2) prolapse, without anterior leaflet tethering. Type B: multiple posterior prolapsing segments. Type C: had an anterior leaflet prolapse, a bileaflet prolapse or leaflet/annular calcifications.

spasm causing VF. The patient required temporary extracorporeal membrane oxygenator (ECMO) and emergent stenting of the left main coronary artery. The patient presented a full recovery without impairment of ventricular contractility and showed a mild residual MR at discharge.

A complete list of major and minor adverse events are presented in Table 3.

**Table 2:** Procedural results

| Variable | *N* = 63 Median (IQR I, III) |
|---|---|
| NeoChords attempted (*n*) | 4 (4–5) |
| NeoChords left (*n*) | 4 (3–4) |
| Two neochords | 2 (3.2%) |
| Three neochords | 20 (32%) |
| Four neochords | 28 (44%) |
| Five neochords | 10 (16%) |
| Six neochords | 2 (3%) |
| Seven neochords | 1 (2%) |
| Operative time (min) | 130 (117.5–150) |
| Intensive care unit stay (h) | 24 (24–24) |
| ≤24 | 50 (80%) |
| 25–48 | 7 (11%) |
| >48 | 6 (9%) |
| Mechanical ventilation time (h) | 3 (2–5) |
| 0 (extubation in the operation theatre) | 7 (11%) |
| ≤3 | 33 (52%) |
| 4–6 | 17 (27%) |
| >6 | 6 (9%) |
| Hospital stay (days) | 8 (6–11) |
| Discharge at home | 9 (14%) |
| Discharge at a cardiac rehabilitation centre | 54 (86%) |

**Table 3:** Safety outcomes

| Variable | *N* = 63 Median (IQR I, III) |
|---|---|
| Perioperative complications (*n*) | |
| Ventricular fibrillation | 3 (5%) |
| CPB/ECMO | 1 (2%) |
| Bleeding requiring >2 blood units | 3 (5%) |
| Surgical revision for bleeding | 0 |
| Apex bleeding or rupture | 0 |
| Conversion to conventional surgery | 0 |
| Major adverse events (*n*) | |
| Death | 0 |
| Stroke | 0 |
| Acute myocardial infarction | 1 (2%) |
| Septicaemia | 2 (3%) |
| Minor adverse events (*n*) | |
| Severe pericardial effusion | 2 (3%) |
| Wound dehiscence | 1 (2%) |
| Gastrointestinal complications needing surgery | 0 |
| Acute renal failure needing CVVH | 0 |
| Onset of persistent AF | 13 (21%) |
| Onset of permanent AF | 1 (2%) |
| PM implantation | 2 (3%) |
| Reoperation for NeoChord failure at 30 days (*n*) | 8 (13%) |
| New NeoChord implantation | 1 (2%) |
| NeoChord re-tensioning | 2 (3%) |
| Mitral valve repair | 3 (5%) |
| Mitral valve replacement | 2 (3%) |

AF: atrial fibrillation; CPB, cardiopulmonary bypass; CVVH: continuous veno-venous haemofiltration; ECMO, extracorporeal membrane oxygenator.

## Feasibility outcomes

The primary early efficacy outcome was 100% (intraoperative post-procedural MR ≤2+).

At discharge, 32 patients (50.8%) presented with no residual MR, 22 (35%) with mild MR (Grade 1+), 7 (11%) with moderate MR (Grade 2+) and only 2 patients (3%) presented with severe MR (Grades 3+ and 4+, respectively). At the 30-day follow-up, MR was absent in 29 patients (46%), mild in 16 (25%), moderate in 10 (16%) and severe in 8 (13%). Among the 10 patients presenting with moderate MR at the 30-day follow-up, 7 of them (70%) presented with annular and/or leaflet calcifications, 2 with anterior leaflet prolapse (20%) and 1 with bileaflet prolapse (10%).

Among patients presenting with MR >2+, 2 patients presented with a recurrence of MR due to anterior leaflet flail. One patient was treated with conventional MV replacement and the other underwent NeoChord reintervention. This patient after another 36 days presented with a recurrence of anterior leaflet flail with severe MR. At this time, he underwent conventional reintervention with MV replacement. The decision to perform NeoChord reoperation was guided by the presence of severe stenosis of the superior mesenteric artery with previous episodes of angina abdominis not treatable with an endovascular approach. Another 5 patients presented with symptomatic severe MR 1 month after surgery, and so they underwent reoperation. Two patients presented with relative elongation of NeoChords, probably due to LV remodelling, and so they were reoperated through the same left minithoracotomy and under 3D TEE guidance a re-tensioning of the NeoChords was performed. Three patients underwent conventional MV replacement because of NeoChord rupture on the posterior leaflet.

Overall, at the 30-day follow-up, 10 patients (16%) had a reduction in MR by two grades, 16 patients (25%) by three grades and 29 patients by four grades (46%).

Clinical improvement was observed in all successfully treated patients. At the 30-day follow-up, 55 patients (87%) were in NYHA Class I, 4 (6%) in NYHA Class II and 4 (6%) in NYHA Class III. Complete data are presented in Table 4.

**Table 4:** Feasibility and efficacy outcomes

| Variable | *N* = 63<br>Median (IQR I, III) |
|---|---|
| Intraoperative post-procedural MR (*n*) | |
| 0+ | 36 (57%) |
| 1+ | 21 (33%) |
| 2+ | 6 (9%) |
| Residual MR at discharge, *n* (%) | |
| 0+ | 32 (51%) |
| 1+ | 22 (35%) |
| 2+ | 7 (11%) |
| 3+ | 1 (2%) |
| 4+ | 1 (2%) |
| Residual MR at 30 days (*n*) | |
| 0+ | 29 (46%) |
| 1+ | 16 (25%) |
| 2+ | 10 (16%) |
| 3+ | 7 (11%) |
| 4+ | 1 (2%) |
| NYHA Class at 30 days (*n*) | |
| I | 55 (87%) |
| II | 4 (6%) |
| III | 4 (6%) |

## Anatomical analysis

Patients were stratified into different groups according to their preoperative MV anatomy. Patients with ideal MV anatomy (Type A) presented isolated central posterior leaflet (P2) prolapse and without anterior leaflet tethering. Patients with acceptable MV anatomy (Type B) showed a posterior leaflet prolapse extending laterally into the P1 or P3 segments, or showed multiple posterior prolapsing segments. Patients with a challenging MV anatomy (Type C) had an anterior leaflet prolapse, a bileaflet prolapse or leaflet/annular calcifications.

Preoperative anatomical characteristics are closely associated with procedural success at 30 days. In Type A patients, the acute success rate was 95% (21/22) and in Type B patients it was 92% (24/26). One patient who belonged to the Type B group was not included in the analysis because NeoChord early failure was related to a surgical technical error that was discovered after reviewing the procedural images. Type C patients showed a 71% (10/14) echocardiographic success rate. Despite the lower freedom from MR >2+ in this last group, we observed a significant clinical improvement in all cases (NYHA Class <II). Complete data are presented in Table 5.

# DISCUSSION

This paper describes the initial experience in two European centres that started a programme of MV repair with TOP-MINI as the first-choice treatment for degenerative MR. We evaluated the safety and efficacy of NeoChord implantation in both low and high surgical risk patients with symptomatic severe DMR, applying only anatomical and pathophysiological exclusion criteria.

This study proves the feasibility and reproducibility of this minimally invasive MV repair technique. Successful placement of two or more NeoChords was possible in all cases, and it was always associated with a significant reduction in MR severity by at least two grades. In 90% of our patients ($n = 57$), NeoChord implantation immediately reduced MR by three or four grades. The rate of conventional MV surgery (repair or replacement) for NeoChord failure at the 30-day follow-up was 8% (5/63), lower than that reported in the TACT Trial (27%, 8/30). It is likely that our good results were facilitated by the improvement in 3D TEE live-imaging guidance [9] and on the experience gained from the second half of patients enrolled in the TACT feasibility trial, in particular, the implantation of multiple neochordae on the prolapsing segment together with a more posterior ventriculotomy, potentially improving clinical results [14, 15].

In parallel to the reduction in MR grade, we observed an improvement in clinical status, assessed by NYHA functional class, in all successfully treated patients. At discharge, all patients were in NYHA functional Class II or less. Even patients with residual moderate MR at the 30-day follow-up exhibited a clinical benefit from the procedure (NYHA Class II or less). This observation is in accordance with previous studies demonstrating a significant clinical improvement when the reduction in MR severity was up to one-third of the preoperative degree (at least moderate residual MR). This result was due to the consequent reverse LV remodelling with improvement in LV function [16, 17].

Among all treated patients, we can identify two groups: low and high surgical risk patients. Although this preoperative differentiation did not influence immediate and early outcomes in terms of clinical improvement and MR reduction. No deaths and no other

**Table 5:** Anatomical features: 30-day evaluation ($n = 62$[a])

| MV type | *n* (%) | Success rate (%) | Residual MR | | | | | NYHA Class | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0+/4 | 1+/4 | 2+/4 | 3+/4 | 4+/4 | I | II | III |
| Type A | 22 (35%) | 21 (95%) | 15 (68%) | 6 (27%) | 0 | 1 (5%) | 0 | 22 (100%) | 0 | 0 |
| Type B | 26[a] (42%) | 24 (92%) | 12 (46%) | 9 (35%) | 4 (15%) | 1 (4%) | 0 | 23 (88%) | 2 (8%) | 1 (4%) |
| Type C | 14 (22%) | 10 (71%) | 2 (14%) | 1 (7%) | 6 (43%) | 4 (29%) | 1 (7%) | 10 (71%) | 2 (14%) | 2 (14%) |

MV: mitral valve; MR: mitral regurgitation.
[a]One patient was excluded from this analysis, due to a technical issue.

major adverse events occurred in hospital except for a case of AMI and 2 cases of sepsis. Most patients required minimal ventilator support (<3 h in 63% of patients), minimal ICU stay (<24 h in 80% of patients) and had a median hospital stay of 8 days. Owing to the low complication rate and high surgical success rate, it seems justified to consider the NeoChord procedure as a possible treatment for patients presenting with suitable anatomy, despite their surgical risk. In the future, we would consider TOP-MINI for early-stage MV pathology since restoration of mitral competence with MV repair removes the haemodynamic burden responsible for LV function deterioration, improving both quality of life and longevity [16]. Moreover, an early surgical procedure in DMR (a leaflet pathology) can restore the normal leaflet motion, preserving the ventriculo-annular continuity 3D dynamics, in contrast to from conventional annuloplasty [17].

We have observed that surgical results are highly dependent on the MV morphological characteristics. In particular, the anatomical analysis performed identifies three different subsets of patients who presented with low (4%), mild (8%) and moderate risk (29%) of procedural failure. This analysis helps us to predict the rate of TOP-MINI early success, providing the right information to the patients. In the future, it will be necessary to improve this anatomical classification using echocardiographic measurements, in order to properly select patients who could be candidates for NeoChord implantation.

In case of NeoChord failure, the patient can be easily and safely converted to conventional on-pump surgery with the same rate of MV repair/replacement as a first-time surgery, since no pericardial adhesions or leaflet modifications occur. Causes of TOP-MINI procedure failure were: NeoChord anchoring rupture, secondary rupture of native chordae and relative elongation of NeoChords.

NeoChords anchoring rupture can occur more easily at the end attached to the MV leaflet than that fixed to the LV muscle. In particular, this event is more frequent for NeoChords implanted on AML, rather than those implanted for the PML, possibly because of the greater dimensions of the AML [14, 15, 18, 19]. In the future, new ventricular entry sites have to be tested to successfully treat AML disease.

Native chordae rupture can be explained as the consequence of a criss-crossing between native chordae and artificial ones, leading to scratching, deterioration and finally rupture of the native subvalvular mitral apparatus. This occurrence was interpreted as the result of a surgical technical error, which provided us the opportunity to further improve the TOP-MINI technique and the imaging guidance protocol. Moreover, once the device crossed the MV, it is moved from commissure to commissure, anterior to posterior under live 3D TEE guidance in order to observe any morphological unexpected changes that would suggest an inappropriate crossing of the valve, avoiding native chordae snatching.

Finally, NeoChords relative elongation was observed as a result of early LV remodelling and LV volume reduction after surgery. For this reason, a slight over-tension is always applied during NeoChord final fixation. In case of NeoChord elongation, a reoperation can be taken into account in order to re-tension NeoChords on the apex.

In conclusion, TOP-MINI allows successful treatment of degenerative MR with a safety profile and good clinical results, even in high-risk elderly patients. Future detailed echocardiographic evaluations will identify its precise anatomical indications. A larger number of patients and adequate long-term follow-up is also needed to assess the definitive value of this therapeutic approach.

**Conflict of interest:** none declared.

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## APPENDIX. CONFERENCE DISCUSSION

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***Dr J. Obadia*** *(Lyon, France):* Your results are encouraging and we will now have to adopt a new denomination, the TOP-MINI. We are more familiar now with the TAVI denomination, and we now have to also accept this newcomer, the TOP-MINI, which means transapical off-pump mitral valve intervention with neochord implantation. So, welcome to this new technology.

This technique has already been evaluated in animal studies, and you reported here the results of two teams working from Padua and Vilnius, on about 62 patients. I have three questions.

My first question concerns the inclusion criteria, which were very large, including low-risk patients. At 30 days the mitral regurgitation was moderate to severe in around 30% of your cases. These are encouraging results for a new technology, but it cannot so far compete with the classical surgical mitral valve repair where the implantation of a ring is an important part of the treatment. So how did you convince the low-risk patients to accept this new technology?

***Dr Colli:*** Well, you are perfectly right. We convinced these patients with the minimally invasive nature of the procedure. The avoidance of cardiopulmonary bypass, the avoidance of cross-clamping, it's absolutely important for the patient, and we strongly believe that the avoidance of these things could improve the recovery of the patient. Second point, you are totally right, the avoidance of the ring could be a problem in patients in whom you have a more central jet. Surgeons fix the ring in order to obtain less tension on the repaired leaflet and prevent possible future dilatation.

So if we start to treat patients with degenerative mitral valve disease of the leaflet earlier when they do not have annular dilatation then we would be able to reach a good coaptation without the ring. This was already published a few years ago from Dr Maisano, also, in the American Heart Journal.

***Dr Obadia:*** My second question concerns the anatomy. Since in the normal anatomy the chordae are not directed towards the apex of the ventricle but, to the papillary muscles which are implanted on the posterior and lateral wall of the left ventricle, is this important or do you have to introduce your device more laterally at some distance of the real apex?

***Dr Colli:*** You are totally right, the anatomy of the subvalvular apparatus is very critical in this procedure. At the beginning, the entry site in the ventricle was on the apex, but after that we shifted to a more lateral part. And as you saw probably in the first slide, we were touching the ventricle under TOE visualisation in order to choose the best entry site that should be perpendicular to the posterior leaflet and not very close at the same time to the papillary muscle. Because one of the possibilities is that if you go too lateral at the same time you can get into the papillary muscle and determine its rupture.

Normally I say that I'm a floor below with respect to the TAVI, in order to be aligned to the mitral valve.

***Dr Obadia:*** Okay, thank you. My last question, how did you decide the number of Gore-Tex? You said that you usually implant three to four Gore-Tex in 75% of the cases. Does this mean that you have to introduce and retrieve the device three or four times, which is a balance between the risk of impairing the apex and the risk of bleeding and, on the other hand, the risk if you do not have enough chordae to have a partial detachment. How do you decide?

***Dr Colli:*** Well, actually this is performed with experience, also based on the TACT feasibility trial. At the beginning only one chordae was implanted. When they started with one chordae, they saw that they had a problem of rupture due to excessive tension on only one element. So everybody thought that it was necessary to wide spread the tension on more chordae mimicking nature. So the three chordae is the minimum number we implant.

***Dr Obadia:*** When you say three chordae, it means six, because you have two arms.

***Dr Colli:*** It means six, exactly. It is a double chordae, so it's six.

***Dr Obadia:*** So it is three introductions and back?

***Dr Colli:*** It is three introductions, this can be challenging. Fortunately we didn't have any big problem on that. Also because the device is very small, it is less than a 12F sheath. And for this reason at the same time we have to have big purse strings, because you need enough strong tissue to close and open the ventricle.

***Dr Obadia:*** Is the apex very different from what we know for the TAVI?

***Dr Colli:*** Well, going laterally it is a more muscular part. It can be a little bit difficult, because sometimes you have coronary branches that you cannot see because they are intramuscular. For this reason we had one patient that had a problem.

***Dr N.M. Van Mieghem*** *(Rotterdam, Netherlands):* I also have a comment. Evidently it is a very elegant technique, but if you look at the rate of 13% of the patients that you need to reconsider within 30 days and a low-risk patient population, because the STS score was I think 1%, and then you were talking about patient selection, and you were mentioning that the ideal patient is the patient that had an A2/P2 prolapse, but those are also the ideal patients for a mitral valve repair as a surgeon, I guess. So from a cardiology perspective, I would want you to do a surgical repair for a durable result. With this in mind, do you think this is a viable technology?

***Dr Colli:*** Absolutely. It's a viable technology. First of all, the cardiologist should send the patient to surgery earlier when the disease is just a leaflet disease and has not become an annular-leaflet disease with a big annular dilatation and ventricle dilation.

Second, considering that if this procedure goes wrong in the sense that you have a recurrence of mitral regurgitation, you have just a small thoracotomy and you don't have any adhesion on the right side of the heart or the left atrium, and you can go with conventional surgery with sternotomy or right minithoracotomy. You just have to take out your chordae, and you have the valve that can be re-repaired or replaced, as you prefer, or whatever you are confident with.

Obviously it is a new technology and it is a new experience that we are having, and the recurrence of mitral regurgitation is a part of the learning curve and of the selection of the patients, but I don't think it was much more different with respect to the MitraClip at the beginning of their experience.

***Dr A. Loforte*** *(Bologna, Italy):* Could you give us more information concerning the re-tension of neochordae. I mean, in your opinion, is it easy, feasible, difficult, after one month, two months, three months, six months, and when you decide eventually to replace neochordae?

***Dr Colli:*** The need for re-tensioning is something that we are seeing in some patients due to the reverse remodelling, because in these patients, you do not have a fixed annulus, so their remodelling is much faster than a normal patient, and these are echo data that will come out in the next months. So you have a reduction of the ventricle and you have a relative elongation of the chordae.

So re-entering in these patients is not that difficult. In some cases in Vilnius the knots were remade; in some other cases we could put a plastic tube below just to re-tension for a few millimetres. So it is possible, it is not that easy, because you can have a little bit of adhesion, but it is not so challenging and is something that has to be considered.

***Dr V.A. Subramanian*** *(New York, NY, USA):* What is the coaptation height, because reduction of posterior leaflet height and bringing the anterior leaflet reservoir for a large coaptation is fundamental for success or recurrence? So

you cleverly missed that point of a coaptation height on the annulus circumference. Can you tell us what it is in the recurrent one?

***Dr Colli:*** In the recurrent one, I mean, this is part of another study that we had.

***Dr Subramanian:*** What is the coaptation height, average mean coaptation height?

***Dr Colli:*** The coaptation that we had was 0.7 cm, but we saw that less than 0.5 was the shortcut to have a recurrence.

***Dr Subramanian:*** That's the problem. You need to have a large coaptation predictably in every patient.

***Dr Colli:*** Yes, that is true. For this reason it is necessary to select the patient, but as I said to you, you have to select the patient but at the same time you don't have to wait too much and too long just to have an annular dilatation, because this is different pathology. It is a combined pathology.