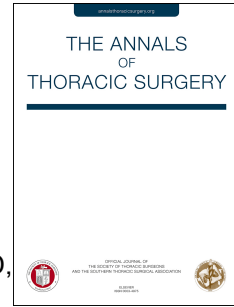


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Left Circumflex Artery Injury after Mitral Valve Surgery: an algorithm management proposal

Running Head: LCx injury after mitral surgery

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Abstract

Background: Left circumflex coronary (LCx) artery injury during mitral valve surgery is a life treating complication. We report our series of patients who developed this complication in a high-volume mitral surgery center.

Methods: Between January 2004 and December 2017 a total of 6501 mitral valve procedures were performed in our center. An injury of LCx occurred in 10 patients (10/6501; 0.15%) after either repair (N=5) or replacement (N=5). Coronary angiography was performed in 9 patients and showed 5 left coronary artery dominance, 2 right dominance and 2 codominance. All data were prospectively collected in our hospital database and retrospectively reviewed.

Results: The suspicion about the injury of LCx raised in the operating room in 5 patients and in to the intensive care unit in the other 5. The postoperative coronary angiography confirmed the LCx lesion. In presence of total occlusion, coronary bypass grafting (N=3) or ring annuloplasty partial removal (N=1) were performed. In case of partial kinking (N=4), percutaneous coronary intervention (PCI) was preferred. In the 2 patients with extrinsic subocclusion, a rescue PCI was initially attempted but both procedures were complicated by artery disruption and stent underexpansion.

Conclusions: In our series LCx occlusion occurred more commonly in patients with left dominant coronary artery circulation. Clinical presentation may be variable. Rescue PCI is a valid option in case of kinking of the artery, in the other cases emergent coronary bypass grafting should be the first choice. Repositioning of the prosthesis may be an option in specific circumstances.

Abstract word count: 247

Abbreviations

CABG: coronary bypass grafting

CPB: cardiopulmonary bypass

ECMO: extracorporeal membrane oxygenation

IABP: intra-aortic balloon pump

ICU: intensive care unit

LCx: left circumflex coronary artery

LV: left ventricle

PCI: percutaneous coronary intervention

TEE: transesophageal echocardiography

Mitral valve disease is the most frequent valvular heart disease, after aortic valve stenosis. The treatment of mitral valve disease is either repair or replacement^{1,2}.

Left circumflex coronary artery (LCx) injury due to placement of annular ring sutures is a serious and sometimes fatal complication^{3,4}. In 1967 Danielson was the first to describe this complication⁵. The incidence range from 0.5% to 01.8%, but it is an underestimated number for two reasons: difficulty in diagnosis and reluctance in publishing negative results⁶. The mechanisms determining LCx lesion are variable, related to either direct injury or distortion of the surrounding tissue. The risk is strongly related to the proximity of the circumflex artery to the mitral annulus, which is variable among patients. It is reported that the risk is greater in dominant left coronary artery circulation^{4,7}. The clinical picture is variable, ranging from ECG changes, arrhythmias, left ventricle (LV) dysfunction, to occasional asymptomatic presentation/clinically silent.

Herein we report our series of patients presenting LCx injury after elective mitral valve repair or replacement.

Material and Methods

The study was approved by the local Ethical Committee, need for informed consent has been waived due to the retrospective observational character of the study.

Between January 2004 and December 2017, a total of 6,501 patients underwent mitral valve repair or replacement in our Institution; among them 10 patients (0.15%), had a clinical relevant left circumflex artery injury. All data were prospectively collected in our hospital database and retrospectively reviewed.

The preoperative characteristics of the patients are listed in Table 1. All in-coming patients in our Institution were preoperatively studied with transesophageal echocardiography (TEE) and coronary angiography; only 1 of these 10 patients didn't undergo coronary angiogram due to his young age at the time of surgery. Coronary angiograms showed a prevalence of dominant left coronary artery circulation (50% left dominant, 20% right dominant, 10% codominant, 20% not determined). Three

patients had been previously submitted to mitral valve repair (2 patients) or mitral valve replacement (1 patient). Patients previously submitted to cardiac surgery were studied with thoracic CT scan to assess relationship and adhesions between the sternum, and the aorta and right ventricle.

Following median sternotomy and aortic-bicaval cannulation, under mildly hypothermic total cardiopulmonary bypass (CPB) the heart was arrested and the mitral valve was exposed through a left atriotomy. After intraoperative evaluation, the valve was repaired or replaced according to the type of lesions and etiology. In redo cases, the prior ring or prosthesis were removed. Mitral valve repair was performed in 50% of the patients (5 patients), through resection of the posterior leaflet (2 patients), edge-to-edge repair (2 patients) or clefts closure (1 patient), associated with the implantation of a flexible posterior band ring with single stitches of Ti-cron 2-0. The other 50% of the patients (5 patients) underwent mitral valve replacement with a mechanical prosthesis with single pledgeted U stitches of Ti-cron 2-0 (3 patients) or two continuous sutures with prolene 0 (2 patients). In 5 patients concomitant procedures were performed (aortic valve replacement, atrial fibrillation ablation, tricuspid valve repair, coronary bypass grafting (CABG) and atrial fibrillation ablation, tricuspid valve repair and atrial fibrillation ablation).

Results

After weaning from CPB all patients underwent intraoperative TEE which showed LV dysfunction in 5 patients associated with arrhythmias (2 patients) or ST-segment changes (3 patients). One patient showed haemodynamic instability evolved into cardiogenic shock (Table 2). The remaining 5 patients were transferred to the ICU (intensive care unit) where, within the first few hours, also developed LV dysfunction at the TEE associated to arrhythmias (2 patients) or ST-segment changes (3 patients) (Table 2). All the complications and adverse events are listed in Table 3. In particular six patients (60%) showed ischemic ST changes, mainly ST elevation in the inferior wall leads and 4 patients had ventricular fibrillation episodes. In all cases the intra- or post-operative TEE showed a moderate to severe left- or biventricular dysfunction and in some cases hypokinetic-akinetic areas in the inferior-lateral wall. In only 1 patient circumflex artery occlusion was documented at the intraoperative TEE

(Fig. 1).

All patients were supported with inotropic agents and in 9 cases with intra-aortic balloon pump (IABP). One patient showed cardiogenic shock during weaning from CPB and required inotropic and mechanical support with IABP and extracorporeal membrane oxygenation (ECMO).

In view of the clinical suspicion of LCx injury all patients were submitted to coronary angiograms which showed a partial kinking of the artery in 4 cases (Fig.2A), an extrinsic subocclusion in 2 cases (Fig.2B) and a total occlusion in 4 cases (Fig.2C). Thereby in 5 cases, where the LCx was partially kinked or suboccluded and in 1 patient in whom the artery was occluded, percutaneous coronary intervention (PCI) and stenting were performed. In 3 of these 5 patients PCI was both unsuccessful and complicated: in particular 2 patients with extrinsic subocclusion did have coronary artery disruption and balloon underexpansion respectively; the third patient with extrinsic subocclusion also experienced artery rupture after PCI attempt. Two of these 3 patients underwent emergent coronary bypass grafting. Instead 3 other patients underwent directly coronary bypass grafting (saphenous venous graft to marginal branch or interventricular posterior branch) without previous PCI attempt and did not have any postoperative complications. In 1 case, where the artery was partially kinked, the annuloplasty ring was partially removed from the antero-lateral commissure to the middle of the posterior annulus with an immediate restoration of the LCx flow, as documented with the intraoperative TEE (Fig.3).

The type of surgery, the postoperative features and the treatment performed in each patient were showed in Figure 4.

The median in ICU stay was 5 days (IQR 5-10.75). All patients required blood transfusions, 50% of the patients showed renal or respiratory complications (requiring prolonged intubation or tracheostomy). One patient required pacemaker implantation for complete AV block. The median length of in hospital stay was 16 days (IQR 14-24). Eight patients were discharged to cardio-rehabilitation center, 1 patient died in ICU for multi-organ failure and 1 patient was transferred to another ICU with ECMO support, for irreversible cardiogenic shock, to be evaluated for heart transplant. This patient died after the transfer because of massive cerebral hemorrhage. One patient

presented a residual severe mitral regurgitation after one year and was submitted to mitral valve replacement, during the postoperative period he developed sepsis and shock and he died for multi-organ failure. The other patients are alive and didn't underwent to redo surgery at the follow-up, median length 4,9 years [1,3-7,2].

Comment

Mitral surgery is not free from complication due to the variable anatomical relationship of the mitral annulus with the aortic valve, the circumflex artery and the bundle of His. Circumflex artery injury due to mitral valve surgery is a life-threatening but often underdiagnosed complication, for its variable presentation and for other possible causes of ischemia and impaired left ventricular contractility following cardiac surgery. In the literature, its incidence varies from 0.5 to 1.8%, but these values are likely underestimated due to both publication bias and challenging diagnosis^{6,8}.

In our Institution, which is a high-volume center for the treatment of mitral valve disease, the incidence of LCx injury after mitral valve surgery was lower (0.15%). This complication seems to be more frequent in patients with a dominant or codominant left coronary configuration⁴. Some authors report a distance as short as 1mm between the mitral annulus and the circumflex artery in left dominant coronary circulation⁹. Virmani and colleagues⁷ were the first to describe the different relationships between the mitral valve annulus and the circumflex artery based on coronary dominance. They reported that in left dominant coronary artery anatomy the distance from the annulus was 4.1 mm (range 3 to 6.5), in codominance 5.5 mm (range 4.5 to 7.5) and in right dominance 8.4 mm (range 6 to 11.5)⁷. Other authors didn't find the same association probably due to the small sample analyzed¹⁰. In our series 50% of the LCx injuries occurred in patients with left dominant coronary circulation, especially involving the most proximal part of the circumflex artery, close to the antero-lateral commissure. We had only 3 patients that had had previous mitral valve surgery and redo surgery did not seem to predispose to this complication.

Diagnosis must be prompt to avoid prolonged myocardial ischemia and left ventricular dysfunction. Clinical presentation ranges from no symptoms, to ECG changes, new regional wall motion

abnormalities, arrhythmias, difficulty in CPB weaning, all the way to cardiogenic shock^{3, 4}. In our patients the suspicion of LCx injury raised in half of the cases intraoperatively, during CPB weaning or immediately following weaning and in the remaining 50% of the patients in the first few hours in ICU.

The mechanisms of lesion were direct trauma, by encircling or transfixing stitches, or indirect trauma, due to tissue distortion related to wide posterior leaflet resection or important annular reduction^{4, 7, 11}. Therapeutic options are either surgical or percutaneous, with no clear superiority of one option with respect to the other. Surgical treatment includes removal and repositioning of the annuloplasty ring or valve, or coronary bypass grafting. PCI is another option which is not completely free from complications, such as vessel rupture during LCx dilatation. In a recent review, Hiltrop and colleagues reported a similar success rate for both surgical and percutaneous treatments (87% vs 81%), but they provide no details on the type of injury⁴.

In summary, our experience confirms that it is very important to be conscious of the risk of LCx injury during mitral valve surgery particularly in patients with left dominant coronary circulation. Prompt diagnosis and interventional strategies are very important to prevent poor outcomes. In particular:

- caution should be used during placement of annuloplasty or valve stitches, especially near the antero-lateral commissure;
- wide posterior leaflet resection and excessively small annuloplasty rings should be avoided;
- early diagnosis with identification of ECG changes, impaired LV contractility and whenever possible assessment of circumflex artery flow with intraoperative TEE is very important;
- if circumflex artery injury is identified intraoperatively, repositioning of the ring or valve can be feasible and it should be immediately considered, or alternately coronary bypass grafting should be performed;
- when recognized postoperatively, PCI can be a valid option when LCx kinking is observed on coronary angiogram. On the other hand, in case of LCx occlusion due to complete extrinsic obstruction, emergent CABG should be preferred.

These considerations have led us to develop an algorithm to guide the decision-making management of these patients that is showed in Figure 5.

This study has numerous limitations. It is a single center retrospective study and has all the limitations related to this model of analysis. Furthermore, we include only those patients with clinical suspicion of left circumflex artery injury after mitral valve surgery. One of the limits of this study is the lack of identification of clinically silent patients, causing an underestimation of the real incidence of this problem. A multicenter registry could be useful to identify the real prevalence of this complication and to promote solutions to treat this complication.

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Table 1: Preoperative/Intraoperative characteristics

Variable	N (%)
Gender (male)	3 (30%)
Age (median, IQR)	64 (43.8-65.8)
Previous mitral valve surgery	3 (30%)
Coronary angiogram dominance:	5 (50%)
Left	2 (20%)
Right	1 (10%)
Codominat	2 (20%)
Not determined	
Mitral valve repair	5 (50%)
Mitral valve replacement	5 (50%)
Other concomitant procedure:	5 (50%)
Aortic valve replacement	1 (10%)
Tricuspid valve repair	2 (20%)
Afib ablation	3 (30%)
CABG	1 (10%)

CABG: coronary artery bypass grafting

Table 2: Time and diagnosis of LCx injury

Site of diagnosis:	Cardiogenic Shock	ST-changes	Arrhythmias (VF)	LV dysfunction (TEE)
Operating Room 5 (50%)	1 (10%)	3 (30%)	2 (20%)	5 (50%)
ICU 5 (50%)	0	3 (30%)	2 (20%)	5 (50%)

ICU: intensive care unit, TEE: transesophageal echocardiography, VF: ventricular fibrillation

Table 3: Postoperative characteristics and Adverse events

Variable	N (%)
ECG changes (ST elevation/depression)	6 (60%)
Arrhythmias (VF)	4 (40%)
TEE (LV dysfunction, hypokinetic-akinetic)	10 (100%)
Inotropic agents	10 (100%)
IABP	9 (90%)
ECMO	1 (10%)
Coronary angiogram post (LCx lesion):	
proximal	6 (60%)
middle	4 (40%)
Coronary angiogram post (LCx lesion):	
total occlusion	4 (40%)
partial kinking	4 (40%)
extrinsic subocclusion	2 (20%)
PCI	6 (60%)
CABG	5 (50%)
Partial ring removal	1 (10%)
ICU stay (days)	5 (5-10.75)
Post-operative Transfusion (RBCs)	10 (100%)
Surgical revision	1 (10%)

(for bleeding)	
Renal complications:	
AKI	4 (40%)
CVVH	1 (10%)
Respiratory complications (intubation > 48 hours or tracheostomy)	5 (50%)
Stroke	1 (10%)
PM implantation and AV block	1 (10%)
Length of hospital stay (days)	16 (IQR 14-24)

AKI: acute kidney injury, CABG: coronary artery bypass grafting, CVVH: continuous venovenous haemofiltration, ECMO: extracorporeal membrane oxygenation, IABP: intra-aortic balloon pump, ICU: intensive care unit, PCI: percutaneous coronary intervention, RBCs: red blood cells, TEE: transesophageal echocardiography, VF: ventricular fibrillation

Figure Legends

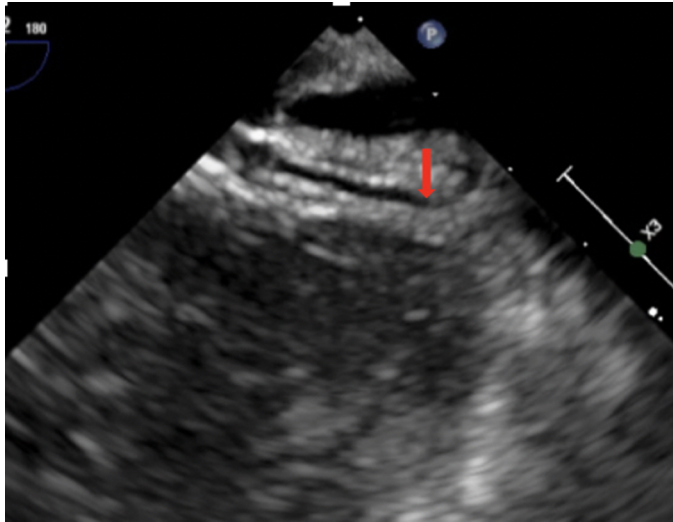
Figure 1: TEE evidence of LCx total occlusion.

Figure 2: A: LCx partial kinkin, B: Extrinsic subocclusion, C: LCx total occlusion.

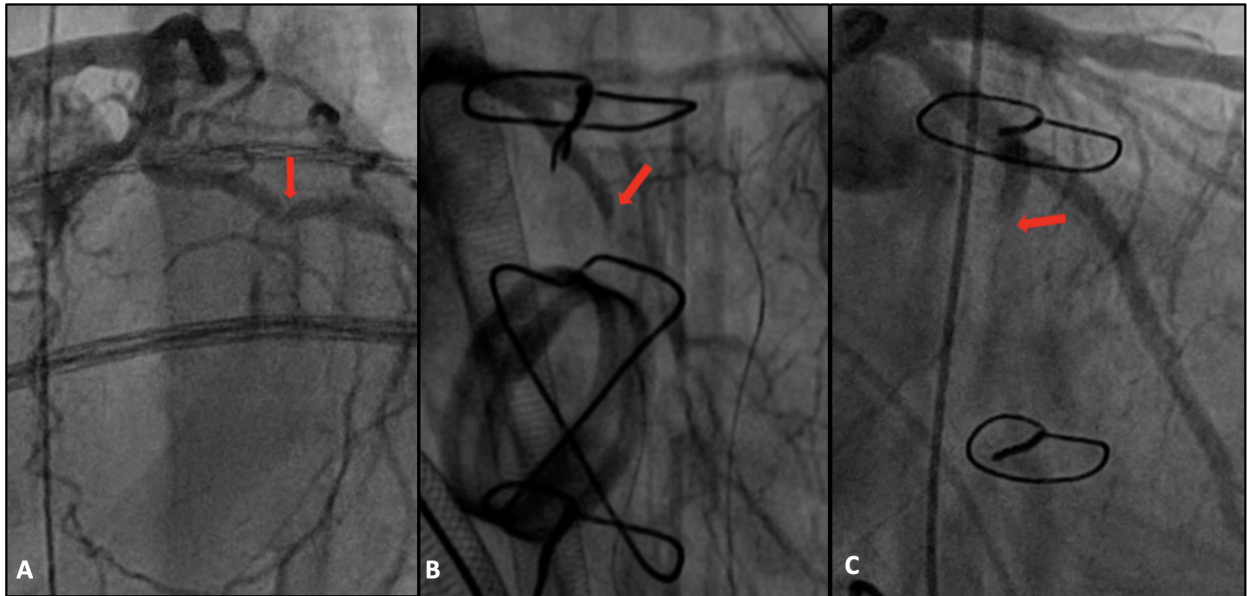
Figure 3: LCx blood flow after partial ring removal.

Figure 4: Patients flow-chart: AVR: aortic valve replacement, CABG: coronary artery bypass grafting, ECMO: extracorporeal membrane oxygenation, ICU: intensive care unit, OR: operating room, PCI: percutaneous coronary intervention, TEE: transesophageal echocardiography, TVr: tricuspid valve repair, VF: ventricular fibrillation

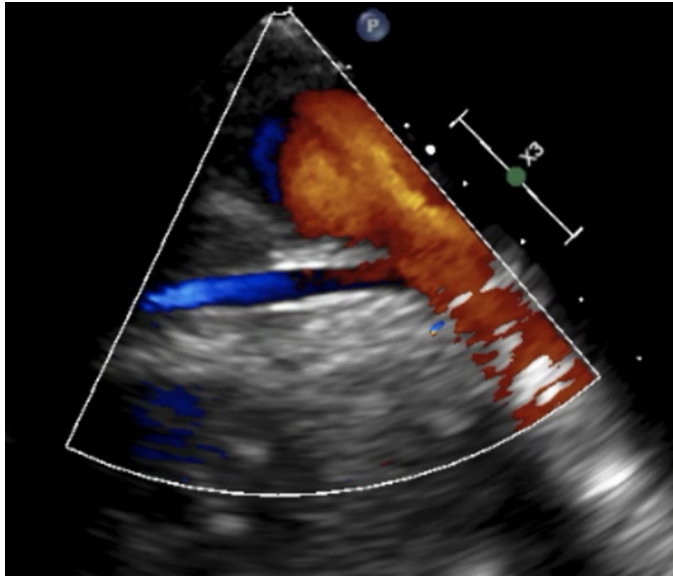
Figure 5: Clinical-therapeutic algorithm: CABG: coronary artery bypass grafting, ICU: intensive care unit, OR: operanting room, PCI: percutaneous coronary intervention



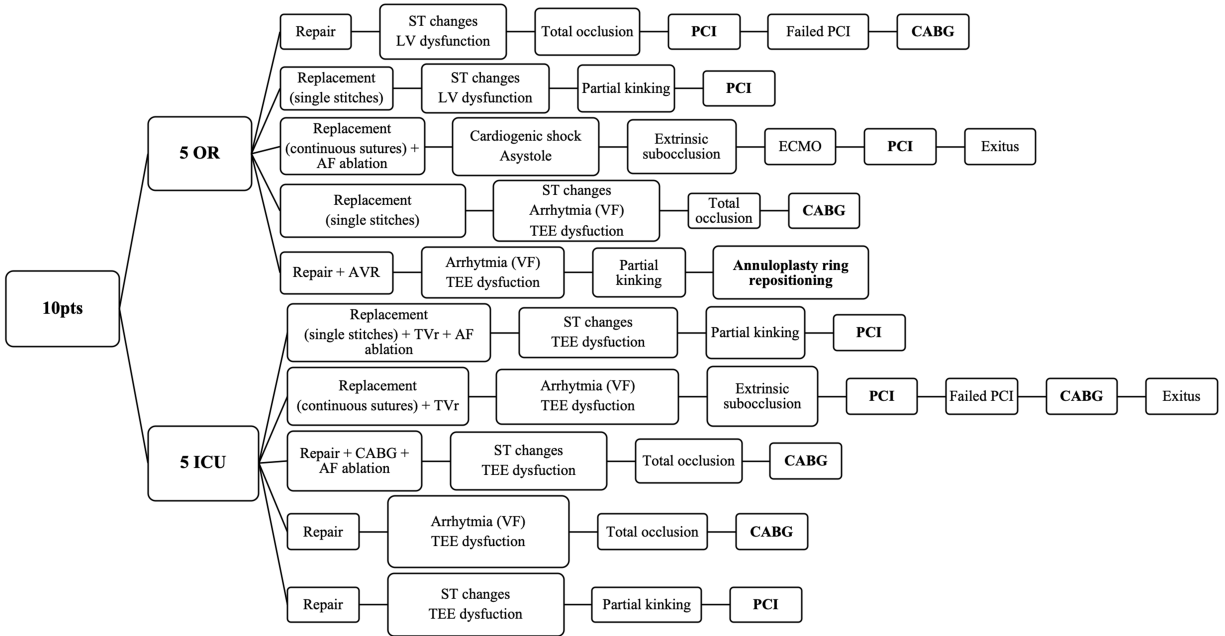
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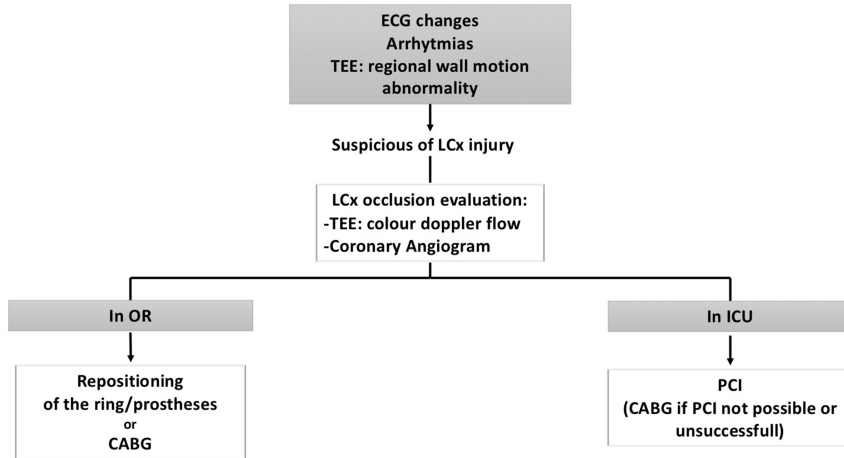


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