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Safety management in cases of pilots who underwent coronary revascularization

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No conflict of interest to declare

Scope of the research

- To review data on risks following different types of coronary revascularization
  - Special attention to the side-effects or complications following 6 months after operational procedure with review of the data available in pilots
- To underline most important risk criteria for the medical assessment of pilots after different types of coronary revascularization and possible management of those risks
- This management of risks related to the CAD after revascularization procedure in pilots assist to prolong their flight carrier.

Concern

- Cardiovascular disease is a leading cause (up to 50%) of all disqualifying conditions for flying duties and most common reason for sudden incapacitation in flight
- The mostly qualified commercial pilots are of advanced age and if fit could fly up to 65 years
- CAD becomes potentially dangerous medical condition in pilots after age of 40 and in most cases remains asymptomatic,
- The early-onset CAD should be considered for pilots population
- Special consideration should be taken in pilots that have already been diagnosed the CAD and had a cardiac event and/or any type of cardiac revascularization

Concern

- Risk assessment is improving with new medical technologies
- Assurance of safe environment of the glass cockpit of modern aircraft, incapacitation training

} more tolerance to certain medical condition

nevertheless

Medical risks should be considered along the occupational risk of CPL pilots as even the second qualified crew member might not mitigate the risk of an incapacitation that will occur at a critical phase of a flight, even usually presenting 1% of the entire flight but very significant for safety (take-off, approach and landing)

Challenges

- Revascularization procedures are palliative, coronary artery disease and related risks for the cardiac events remain and potential sudden incapacitation is essential to be consider
- Standards for fitness to fly are based on structural, anatomical criteria mainly
- Surgical and cardiological guidelines are updated much faster than regulation of aviation authorities
- Regulations are controversial and differ significantly from clinical recommendations and standard practice in non-aircrew population
- Difficulties in assessment when multiple vessel lesion and/or revascularization is presented
- Taking into consideration all known data, regulatory and statistical (as 1% rule) – the approach remain very individual

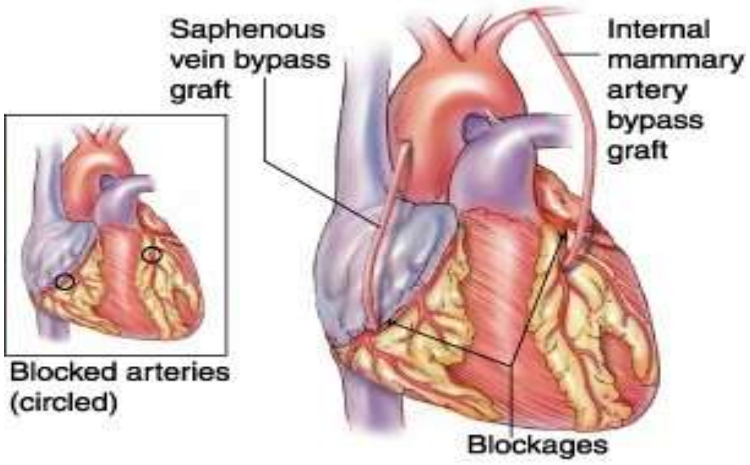
Requirements

EC Regulation 1178 MED.B.010 & related AMC1 MED.B.010

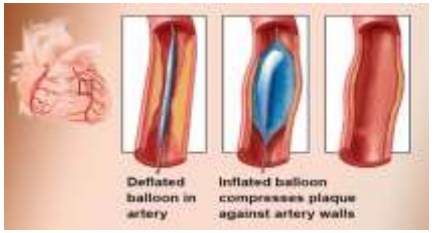
- Following revascularisation for CAD revalidation of class 1 medical certification (commercial pilots) is possible by the Licensing Authority after 6-months period under the following conditions:
  - Reduction of any risk factor to an appropriate level
  - No medication to control the cardiac symptoms
  - Acceptable secondary prevention treatment
  - Detailed clinical report of the event and operative procedure with all coronary angiograms
    - No stenosis >50% in any untreated vessel, vein or graft or at the site of an angioplasty/stent (exception vessel subtending MI);
    - Not more than 2 stenosis between 30-50% within the coronary tree;
    - Coronary tree to be satisfactory, particular attention should be paid to multiple stenosis and /or multiple revascularisations;
    - Not >30% untreated stenosis in LM and proximal LAD;
    - Ejection fraction to be >50%
    - No reversible myocardial ischaemia
  - Annual cardiology follow-up or as clinically required

Types of revasculatization

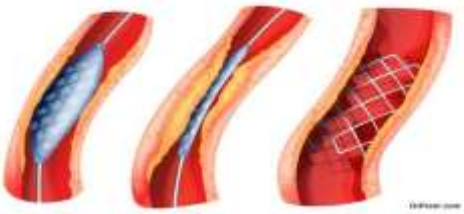
- coronary artery bypass graft surgery (CABG)



- percutaneous coronary intervention (PCI), catheter-based
  - ✓ angioplasty



  - ✓ stent
    - Bare Metal Stents (BMS)
    - Drug Eluting Stents (DES)



Post revascularization risks

Primarily associated with the CAD itself and its progression

- Risk factors for CAD (atherosclerosis) and its progression
- Perioperative Risks

Risks related to the procedure of re-vascularization after 6m

- MACE following PCI
  - Restenosis
  - Thrombosis
  - Minor and major bleeding (untiplatelet therapy)
- Following CABG
  - Graft restenosis
  - Graft thrombosis

- Stenosis of the native non target artery

Risks

- For aeromedical certification we should analyse individually all possible risks that are very much connected with each other and consider the safe performance of pilots in relation to favorable long-term outcome following the revascularisation.
- Both, procedure related effects and native CAD progression have to be equally addressed to minimize the risks of possible cardiac event

Risks

to CAD itself

Non-modifiable

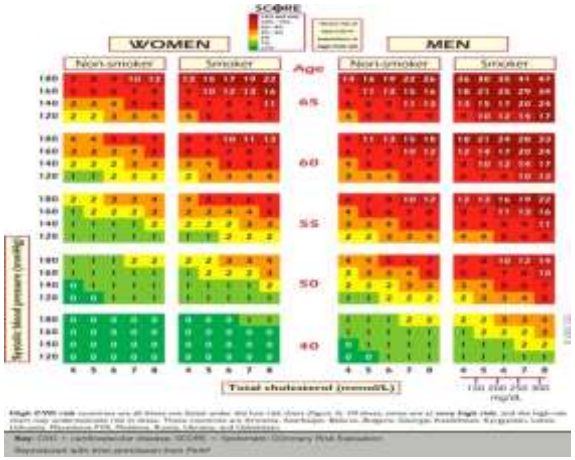
- Age
- Gender
- Positive family history
- Socioeconomic status

Modifiable

- Physical inactivity
- Smoking
- Diet, dyslipidemia and obesity
- Hypertension

Diabetes

Framingham-based Risk Chart



AMC1 MED.B.010 (k)

(4) applicants should have reduced any vascular risk factors to an appropriate level

Risks

from AsMA clinical Practice Guideline[1]

- Cardiac death and nonfatal MI (1-3% per year)
- Second revascularization procedure 2-8% per year
- New significant lesions (≥ 50% stenosis) may develop at other sites at rates of 7-15% per year
- Cardiac event rate:

in 1 year	in 2 years	in 5 years
1%	2,7%	3,6%

The progression of CAD should not be underestimated after the revascularization procedure

1 **Clinical Practice Guideline** for CORONARY ARTERY REVASCULARIZATION Developed for the **Aerospace Medical Association** by their constituent organization American Society of Aerospace Medicine Specialists

Risks

Perioperative and post operative risks

- Individual CAD conditions
  - Initial degree of a lesion
    - better prognostic have individuals with normal left ventricular function, no prior myocardial infarction, age > 50y
  - Number, size and significance of coronary arteries involved
    - single or double vessel disease has less risk than 3-4 vessels lesion;
    - smaller arteries are more prone to restenosis after PCI;
    - in LM or LAD lesion special consideration is applied;
  - Concomitant lesion of other arteries (aorta, carotid, limb)
    - for pilots population the associated lesion of carotid arteries has significant concern and shall be always considered in fit assessment

Risks

Perioperative and post operative risks

- CAD severity is related to that of other atherosclerotic lesions. Additional systematic screening of other concomitant atherosclerotic lesions is recommended, especially in patients having multivessel CAD disease, left main disease, and/or already diagnosed with other concomitant atherosclerotic lesions.
- CAD is more often concomitant to carotid artery disease (64-80%)[2].
- CAD evolution is more severe if associated with PAD and diabetes[3]

2. Imori Y, Akasaka T et al. Co-existence of carotid artery disease, renal artery stenosis, and lower extremity peripheral arterial disease in patients with coronary artery disease. *Am J Cardiol.* 2014 Jan 1;113(1)

3 Sung W.C., Byung G. K. et al. Prediction of Coronary Artery Disease in Patients With Lower Extremity Peripheral Artery Disease, *Int Heart J* 2015; 56

Risks

MACE following PCI

- Two major types of coronary artery stents are commonly deployed:
- Bare Metal Stents (BMS)
  - Had better result than the balloon angioplasty
  - There is high incidence of late stent restenosis with up to 25 – 30% can be seen beyond one year following stent placemen[4]
- Drug Eluting Stents (DES)
  - Use of DES significantly ameliorated the restenosis problem and is accompanied by better clinical outcomes as compared with BMS use
  - At the end of medium 24 (14-34) months period follow-up, the overall death rate was 0.7%. MACEs were observed in 12.4%.(Chinese study on the long-term outcome of DES in patients with early-onset coronary artery disease (CAD) - < 50 years old) [5]

4. Usha Kiran, Neeti Makhija. Patient with Recent Coronary Artery Stent Requiring Major Non Cardiac Surgery, Indian J Anaesth. 2009 Oct; 53(5): 582–591.W.E. Bennett, T. Toole et al.

5. Guipeng An, Zhongqi Du, Xiao Meng et al. Risk Factors for Long-term Outcome of Drug-eluting Stenting in Adults with Early-onset Coronary Artery Disease, *Int J Med Sci* 2014; 11(7):721-725.

Risks

A.Moulias and D.Alexopoulos[6]

- In BMS implantation target lesion events may occur the 1 year, thereafter – the new adverse cardiac events occur during 2 to 5 years due to the progression of the disease at other segment of the coronary tree
- Annual hazard rate of

non-target lesion	target lesion
6,3%	1,7%

6 Athanasios Moulias, MD and Dimitrios Alexopoulos, Patras University Hospital, Patras, Greece Long-Term Outcome of Percutaneous Coronary Intervention: The Significance of Native Coronary Artery Disease Progression MD, Clin. Cardiol. 34, 10, 588–592 (2011) Published online in Wiley Online Library (wileyonlinelibrary.com)

Risks

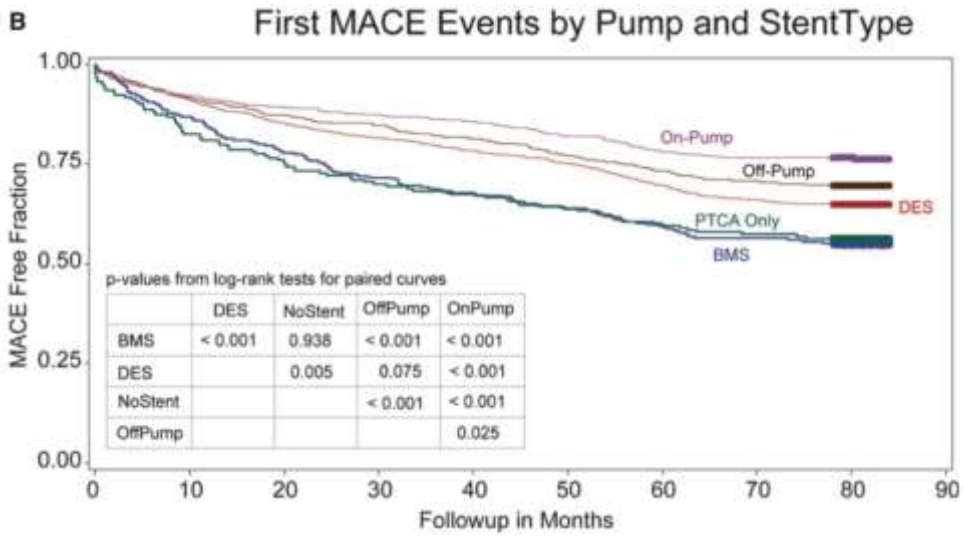
- A total number of 1038 patients with PTCA (n=499), CS (n=294) or CABG (n=245) were followed-up over a mean time of 6.4+/-1.8 years. Forty-two patients (4.0%) were lost to follow-up, leaving a study population of 996 subjects who were available for analyses. The primary and secondary endpoints were mortality and major adverse cardiac events (MACE), respectively. Overall death rate was 19.3%. Age, pulse pressure, smoking, diabetes, serum LDL cholesterol levels and left ventricular ejection fraction rather than the intervention type independently predicted mortality. The incidence rate of MACE was 53.7%.

  Compared to PTCA patients, CS patients had lower (hazard ratio 0.693; 95% confidence interval 0.514-0.793) and CABG patients the lowest risk of MACE (hazard ratio 0.343; 95% confidence interval 0.261-0.450). Further risk factors for MACE were serum LDL cholesterol levels, three-vessel coronary artery disease and left ventricular ejection fraction of <30%[7].

7. Volzke H, Henzler J. et al. **Outcome after coronary artery bypass graft 13. surgery, coronary angioplasty and stenting.** Intnl J Cardiol. 007 Mar 2;116(1):46-52. Epub 2006 Jul 5.

MACE: PCI versus CABG[8]

	PCI	CABG
Overall MACE	**41.8%**	**29.2%**
CABG	3.1%	0.6%
AMI	3.1%	2.2%
PTCA	1.4%	0.3%
Stent	9.4%	5.7%



Prospective study 3156 patients: 968 CABG, 2188 PCI, **7 years follow-up**

Comparable patients undergoing coronary revascularization appear to benefit from improved long-term survival and reduced MACE with CABG versus PCI.

8. Kurlansky P, Herbert M, Prince S, Mack MJ. Coronary Artery Revascularization Evaluation—A Multicenter Registry With Seven Years of Follow-Up. Journal of the American Heart Association: Cardiovascular and Cerebrovascular Disease. 2013;2(2):e000162

5 years mortality risk [9]

	PCI	CABG
Diabetes	15.7%	10.7%
Multivessel disease	11.5%	8.9%
	The **mortality benefit** of CABG over PCI in patients **with multivessel disease increased with duration of follow-up.**	
LM disease	10.7%	10.5%
Syntax score	The mortality benefit of CABG over PCI tended to increase with increasing SYNTAX scores.	

5 year all-cause mortality
in trials that did PCI with bare-metal stents
- 8,7% after PCI
- 8,2% after CABG (HR 1·05, 95% CI 0·82–1·34; p=0·72),

in trials that did PCI with drug-eluting stents
- 12,4% after PCI
- 10·0% after CABG (1·27, 1·09–1·47; p=0·0017).

5 year mortality
- Significantly lower after CABG than after PCI.
- Benefit of CABG over PCI in patients with multivessel disease and diabetes, but not in patients with multivessel disease without diabetes.
- No benefit for CABG or PCI in patients with left main disease.

Consideration of coronary lesion complexity is important when choosing the appropriate revascularisation strategy.

9. Head SJ, Milojevic M, Daemen J, et al. Mortality after coronary artery bypass grafting versus percutaneous coronary intervention with stenting for coronary artery disease: a pooled analysis of individual patient data. Lancet 2018; 391: 939–48

Completeness of revascularisation (CR) [10]

Randomized trial **3212 patients: CABG-CR 1015 patients, CABG-IR 505 patients, PCI-CR 968 patients, PCI-IR 724 patients**

	PCI	CABG
Complete revascularisation	57.2%	66.8%

5 years follow-up:

- higher risk for death from any cause, AMI and stroke (HR 1.48) in PCI with incomplete revascularisation
- **no significant difference between patients undergoing CABG with CR and those undergoing PCI with CR** regarding the risk for death from any cause and the composite of death, myocardial infarction, and stroke

For the treatment of left main or multivessel CAD, PCI resulting in CR is associated with a similar long-term survival rate compared to CABG resulting in CR.

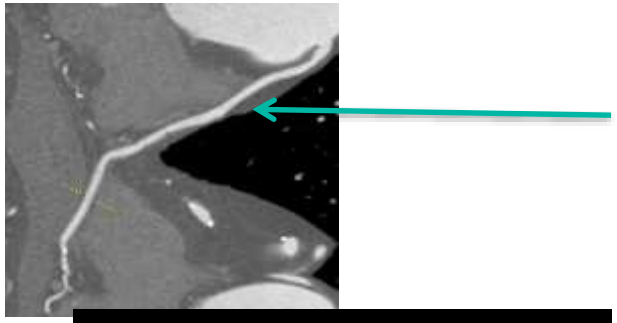
10. Ahn JM, Park DW, Lee CW, et al. Comparison of Stenting Versus Bypass Surgery According to the Completeness of Revascularization in Severe Coronary Artery Disease: Patient-Level Pooled Analysis of the SYNTAX, PRECOMBAT, and BEST Trials. JACC Cardiovasc Interv 2017;10:1415-1424.

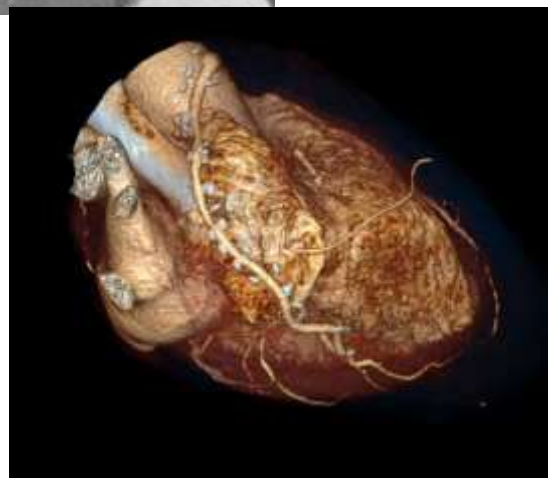
Completeness of revascularization

Makes sense

- Complete revascularization is preferable in pilots
- In complete revascularization by CABG (3 and more grafts) the long term outcome is better than of 2 vessels revascularization (progression of the disease)
- If complete revascularization no significant difference between patients undergoing CABG and those undergoing PCI regarding the risk for death from any cause and the composite of death, myocardial infarction, and stroke

Complete Arterial Revascularisation

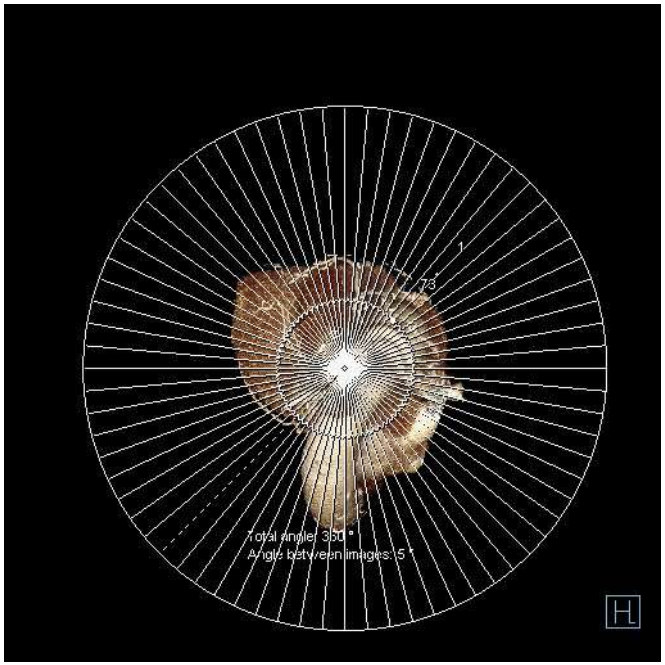


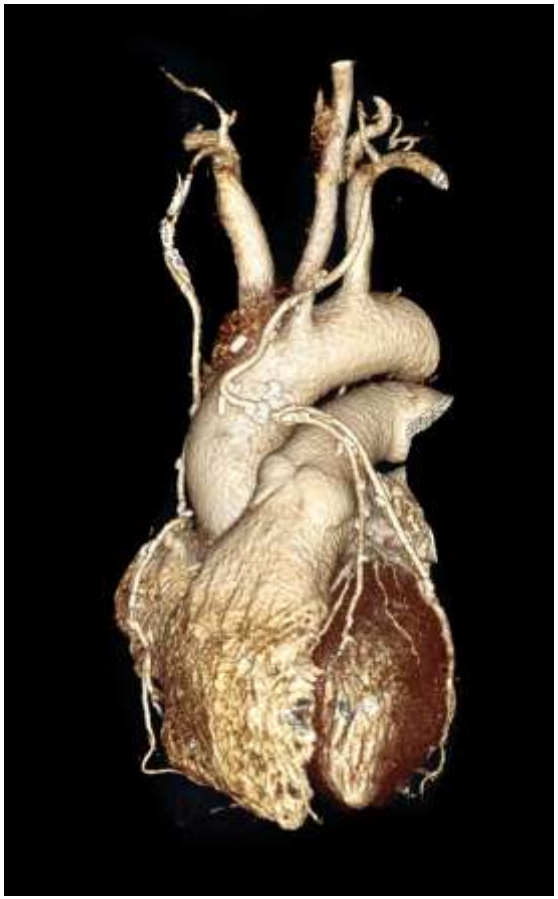


RAG-PDA

Y and sequential anastomoses: LAD, Diag, OM

Patient is practicaly healthy





situ RIMA-RCA, LIMA-LAD

RAG-PDA

in situ RIMA-RCA, Y LIMA-RAG (OM)

Example of complete arterial revascularisation in diabetic patient. Many stenosis and atherosclerotic plaques on native coronary arteries

MACE following PCI
in aviators

- Cardiac outcomes in aviators demonstrates a MACE rate higher than what is reported in the general literature (25% vs 10%). The increased MACE was driven by repeat revascularization procedures, in particular repeat coronary stenting [11].

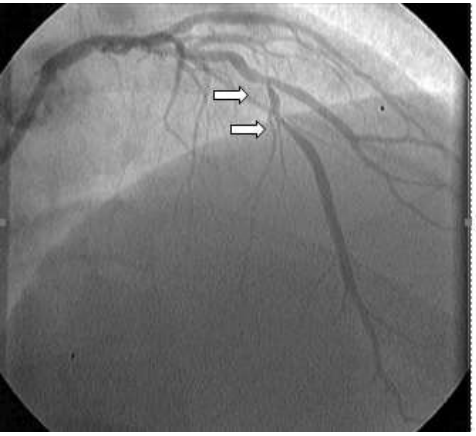
11. CARDIAC OUTCOMES IN AVIATORS AFTER REVASCULARIZATION FOR CORONARY ARTERY DISEASE: AVIATOR STUDY
1 Civil Aerospace Medical Institute, FAA, Oklahoma City, OK;2Cardiology, Naval Medical Center San Diego, San Diego, CA; 3FAA,Oklahoma City, OK; 4NAMI, Pensacola, FL. Presentation at AsMA Meeting 2015

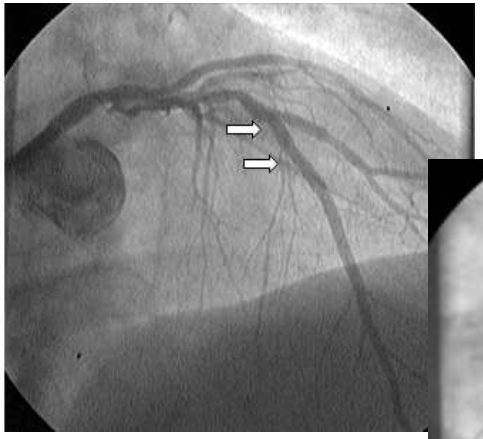
PCI

ATPL pilot, case 1

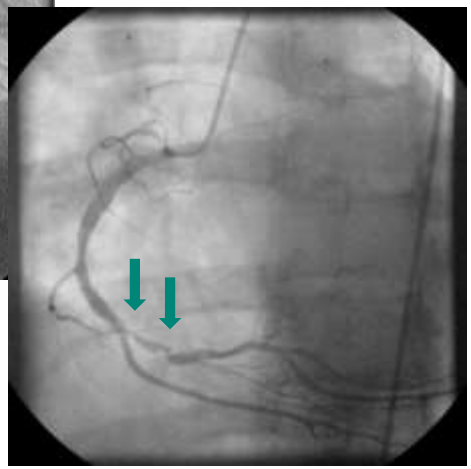
- ATPL pilot, 1958 yob
- 2004, March(46yrs) – PCI after AMI:
  - LAD middle – stenosis 75-90% - stenting
  - RCA middle, seg II – stenosis 25%
  - RCA middle after bifurcation with right marginal branch – stenosis 95-99% - stenting

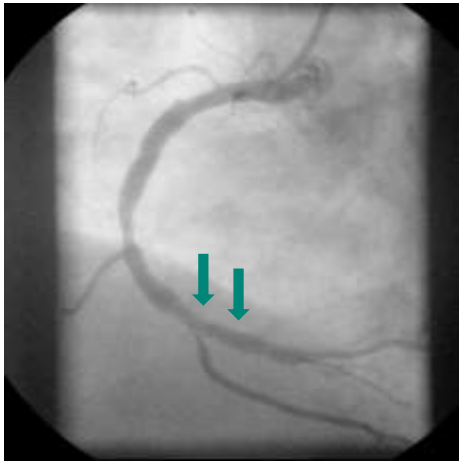
LAD





RCA



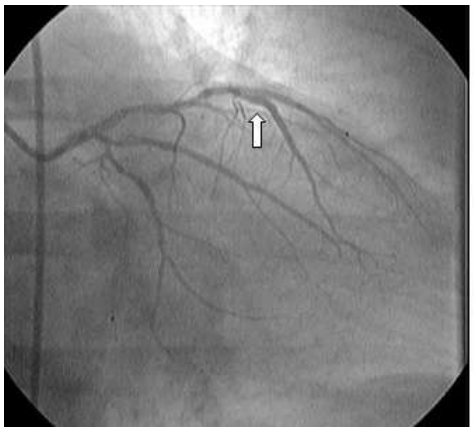


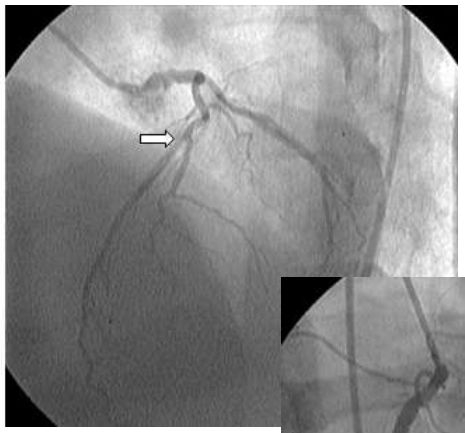
PCI

ATPL pilot, case 1

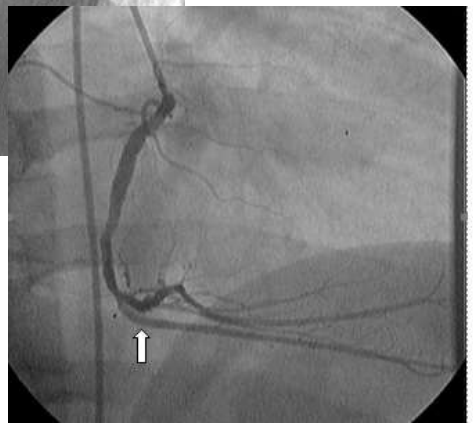
PCI in 6 month

LAD





RCA



- 2004 Sept – no restenosis, stress test neg., non-smoker, normal blood pressure – certified for Class 1 with OML limitation

PCI

ATPL pilot, case 1

- 2005, 2006, 2007, 2008 – aeromedical examinations were performed in 6 months period (TML)
  - all modifiable risks were reduced, non-smoker
  - LDL, HDL normal limits, elevation of triglicerides
  - Normal glucose level
  - BP – 120-140/80-90 mmHg
  - Stress tests – unique single SVPB and VPB
  - ECHO cardio – hypokinesis of posterior-inferior wall basal & middle segments of LV, LV hypertrophy of mixed type, induration of ascending Ao, EF – 55-62%

PCI

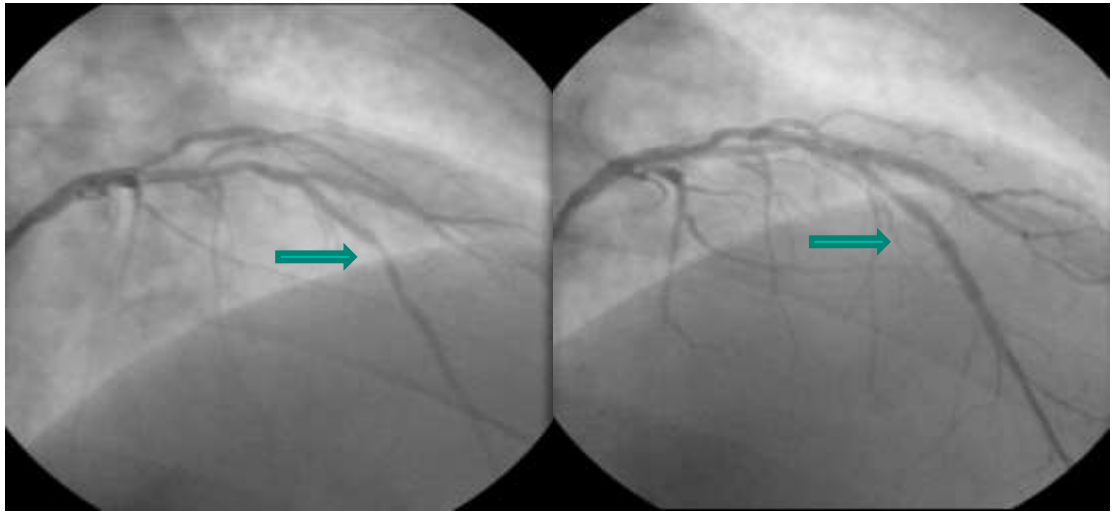
ATPL pilot, case 1

- 2009/03/02 – PCI as required by standards
  - RCA middle, seg II – stenosis 70% - stenting
  - LAD distal segment after the previous stent – stenosis 45% (lesion de-novo) - stenting
- 2009/09/07 – 6 months follow-up PCI as required by standards
  - LAD distal segment after the previous stent – stenosis 75-90% (lesion de-novo) - stenting

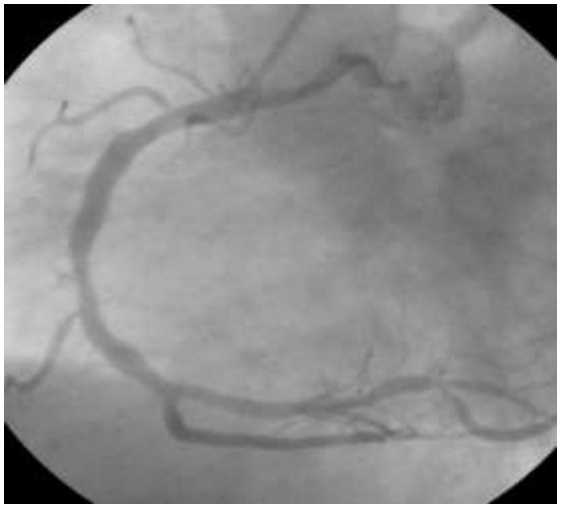
PCI

ATPL pilot, case 1

LAD



RCA after stenting

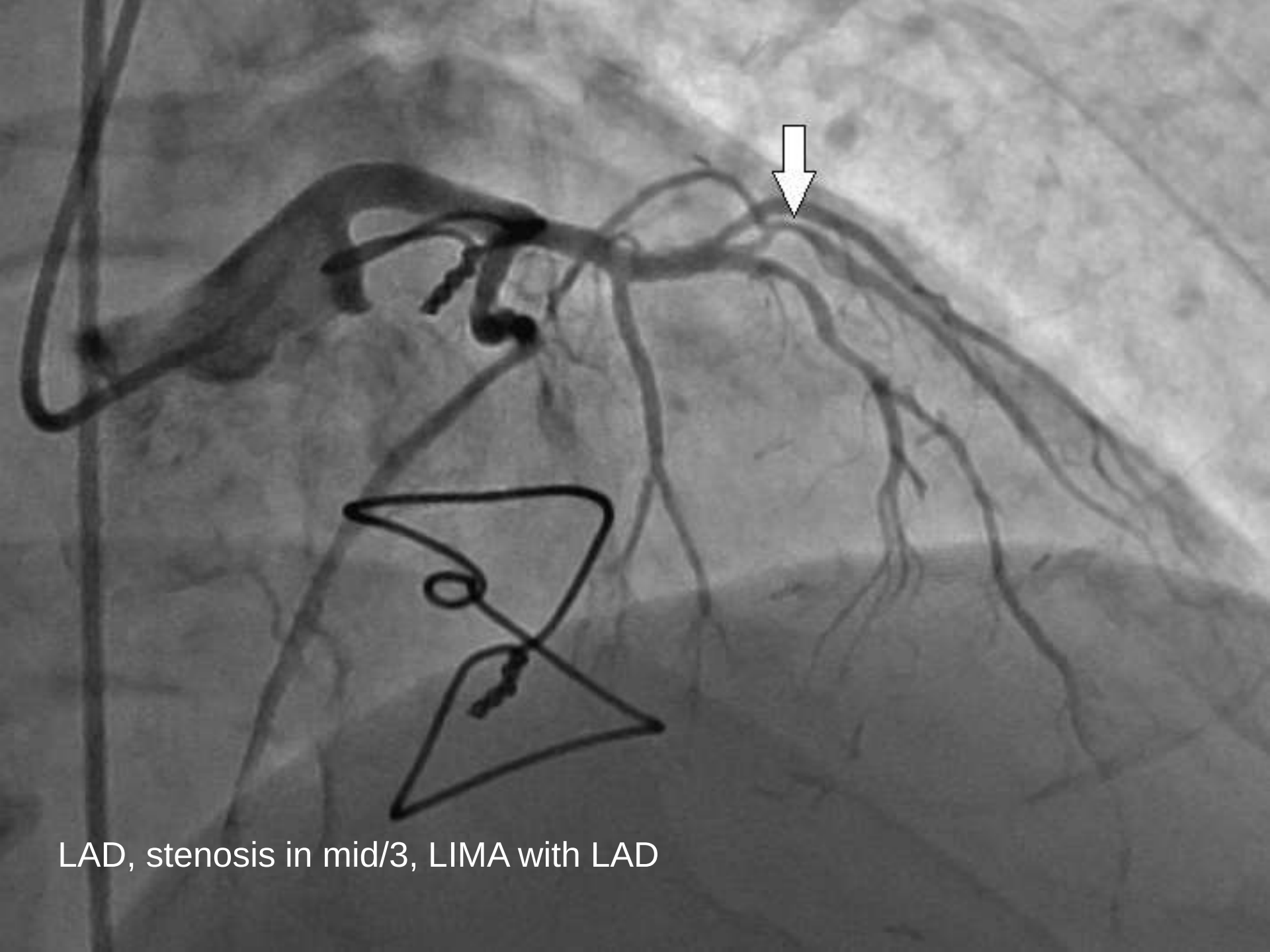


in 2009 aeromedical decision was not fit for flying duties

CABG

ATPL pilot, case 2

- ATPL pilot, 1955 yob,
  - Military IL 76, turbo jet, cargo operations in the past
  - ATPL helicopter dual control
- 2007 – at aeromedical examination (52 years)
  - treadmill test: positive,
  - Hypertension under control,
  - PCI: CAD, multi vessel lesion,
    - LAD - stenosis 50% proximal/3, 50% middle/3,
    - LCX stenosis 75% proximal with extention to
    - OM sever stenosis from mouth.
- 2008 – CABG
  - CABG with LIMA to the LAD,
  - Sequential auto venous CABG PDA_{LCA}
- 2013 – first time applied in AeMC, Chisinau. After satisfactory full cardiologic examination and acceptable laboratory tests – fit for Class 1 with OML limitation



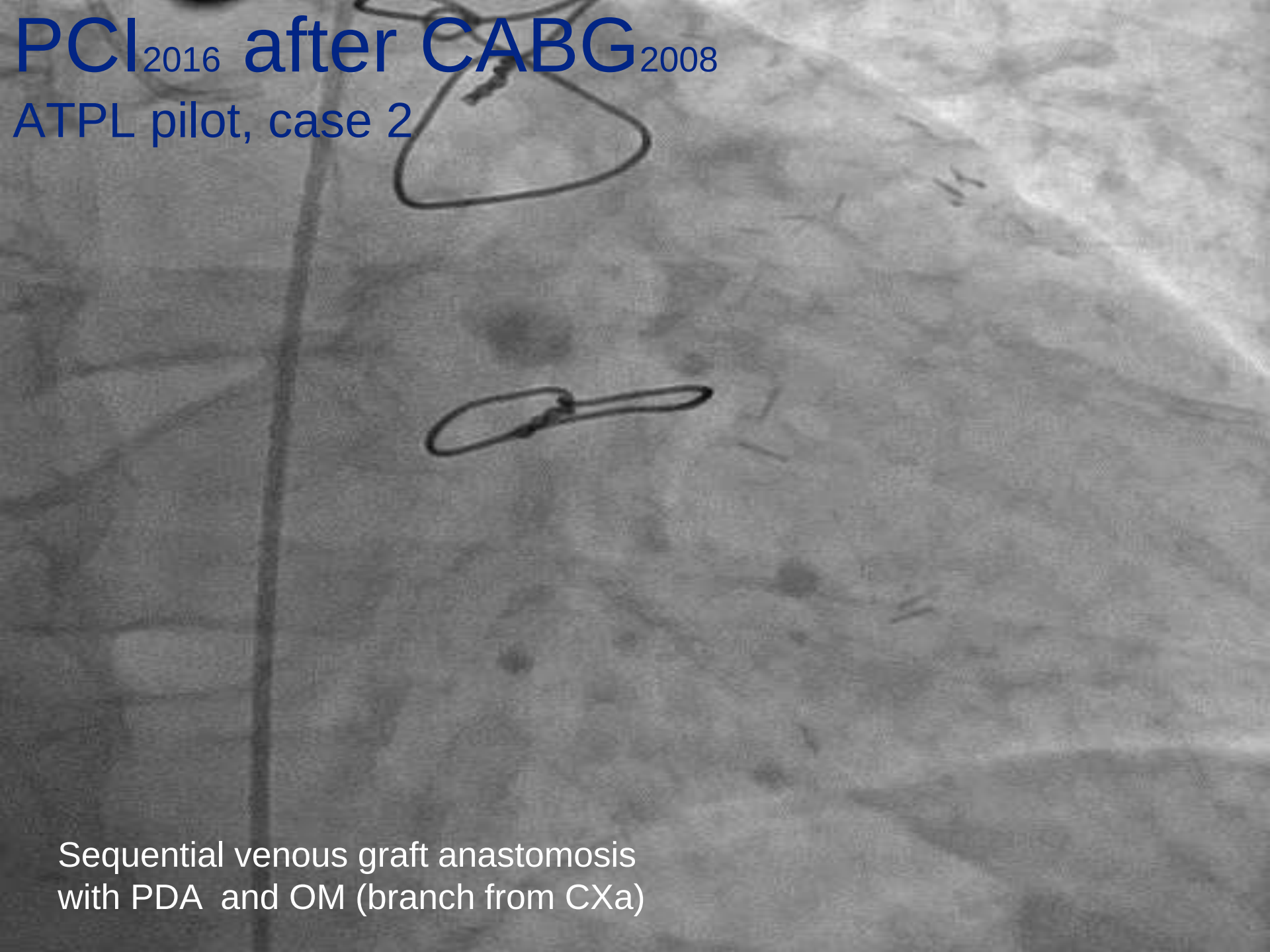
LAD, stenosis in mid/3, LIMA with LAD

PCI$_{2016}$ after CABG$_{2008}$

ATPL pilot, case 2

PCI$_{2016}$ after CABG$_{2008}$

ATPL pilot, case 2



Sequential venous graft anastomosis
with PDA and OM (branch from CXa)

CABG

ATPL pilot, case 2

- 2018, February
  - Holter 24h ECG & BP – rare SupraVPB and VPB
  - Blood pressure 140/90 mmHg
  - Total cholesterol 3,66 mmol/l
  - triglycerides – 0,69 mmol/l
  - Treadmill – negative, with medium tolerance to physical exercises
  - EF – 60%
  - medication: ACE-inhibitors, β-blockers, Rosuvastatin, cardiomagnil.
- Fit for Class 1 medical certificate with OML limitation

General prognostic data

AsMA clinical Practice Guideline[1]

- Cardiac death plus nonfatal MI event rates are comparable for CABG versus PCI with a trend usually favoring CABG.
- Next revascularization rates are significantly lower for CABG versus PCI and for stent versus angioplasty
- Extensive and severe coronary disease, particularly if the left main coronary artery is involved with disease, even if revascularized will likely be viewed unfavourably[12]

12. Guidelines for the Assessment of Cardiovascular Fitness in Licensed Aviation Personnel 2012. Transport Canada Civil Aviation Medicine, Ottawa, Ontario, February 2012
Extensive and severe coronary disease, particularly if the left main coronary artery is involved with disease, even if revascularized will likely be viewed unfavourably

Predictors

- Understanding of the CAD progression as a major cause of post revascularization cardiac event
- Regular follow-up with evaluation of all modified risk factors with their correction. In special:
  - normal systolic blood pressure (≤120mm Hg) and LDL levels ≤70mg/dL slowest the progression[2]
  - In contrary high baseline glucose level, increased level of triglycerides contribute to the progression of the disease

Risk factors modification

conditions for recertification

- the applicant shall be non-smoker;
- serum lipid levels are maintained at normal levels and medications for lipid lowering are compatible with flying duties;
- glucose level in normal limits
- weight loss
- hypertension shall be controlled and if by medication, it shall be acceptable
  - non-loop diuretic agents;
  - certain (generally hydrophilic) beta-blocking agents;
  - ACE Inhibitors;
  - angiotensin II AT1 blocking agents (the sartans);
  - slow channel calcium blocking agents.

Precise assessment

FFR, IVUS in aeromedical certification

- The new investigation methods as Fractional Flow Reserve (FFR), Intravascular Ultrasound (IVUS) might better show the lesion and myocardial ischemia
  - in borderline lesions, it is necessary to apply other procedures like IVUS, FFR.
  - The examining interventional cardiologist shall be informed to use one of these procedures for the precise assessment of the extent of stenosis in doubtful cases[7]
- FFR assists in evaluation of functional relevance of CAD - the assessment of myocardial perfusion under stress and hemodynamical significance of stenosis

- Perioperative planning of the surgery and communication of surgeon and AME are essential (e.g. complete revascularization) for pilots
- Communication with pilots about the quick address for a medical assistance in Acute Coronary Syndrome. Ideal timing to perform a stenting procedure is 1.5 – 2.0 hours from symptom onset


Thank you for your attention!
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