

# Postoperative Myocardial Ischemia and Infarction

John E. Ellis MD

Professor

Dept of Anesthesia and Critical Care  
The University of Chicago

[johnellis1700@gmail.com](mailto:johnellis1700@gmail.com)



# Things change!



# Stop the presses!

Journal of the American College of Cardiology  
© 2007 by the American College of Cardiology Foundation and the American Heart Association, Inc.  
Published by Elsevier Inc. Vol. 50, No. 17, 2007  
ISSN 0735-1097/07/\$32.00  
doi:10.1016/j.jacc.2007.06.013

## ACC/AHA GUIDELINE

### ACC/AHA 2007 Guidelines on Perioperative Cardiovascular Evaluation and Care for Noncardiac Surgery

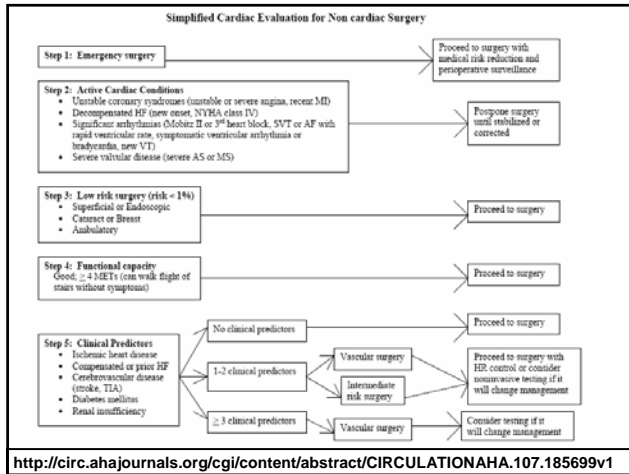
A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery)

Developed in Collaboration With the American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, and Society for Vascular Surgery

#### WRITING COMMITTEE MEMBERS

Lee A. Fleisher, MD, FACC, FAHA, Chair; Joshua A. Beckman, MD, FACC<sup>†</sup>;

<http://circ.ahajournals.org/cgi/content/abstract/CIRCULATIONAHA.107.185699v1>



- Personal recommendations
- Less invasive surgery = less workup?
  - Limited preoperative cardiac evaluation
    - Symptomatic patients
    - Very high risk?
    - Patient with a coronary stent

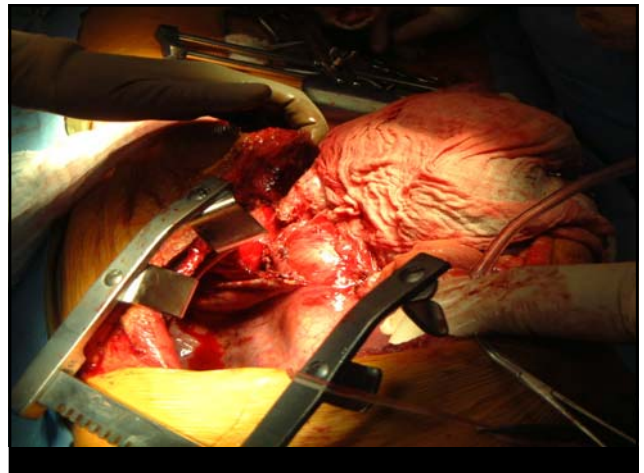
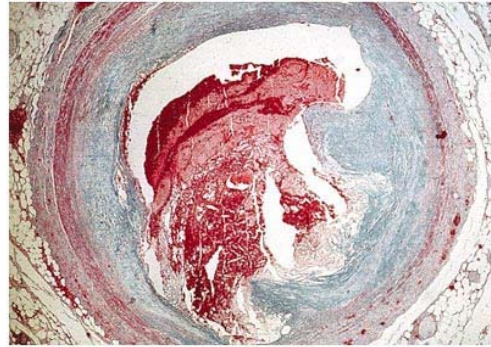
- Personal recommendations
- Routine pharmacologic prophylaxis
    - Beta blockade
    - Statins
    - Aspirin +/- clopidogrel

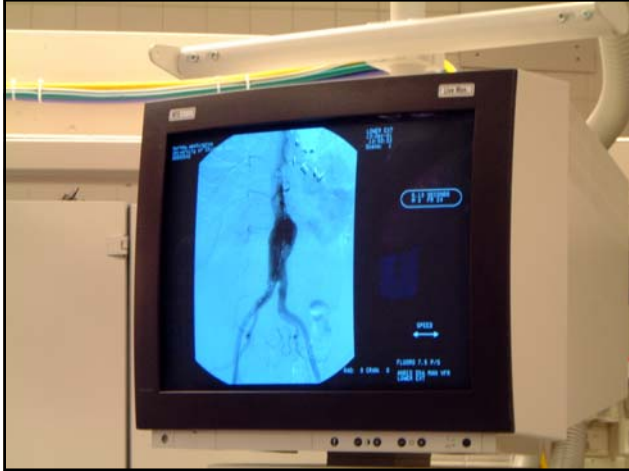
- Personal recommendations
- Aggressive prophylactic perioperative care
    - Normothermia
    - Euglycemia
    - Correct anemia?

Personal recommendations

- Aggressive prophylactic perioperative care
  - Excellent analgesia
  - Troponin surveillance
  - Cardiologist followup

## Acute Thrombosis





## CEA vs CAS: Cardiac Events?

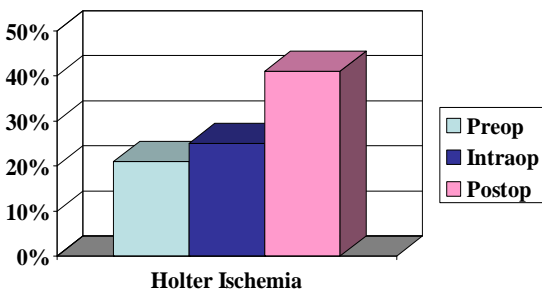
Therapy and prevention 483

### Carotid artery stenting versus endarterectomy in relation to perioperative myocardial ischemia, troponin T release and major cardiac events

Harm H.H. Feringa<sup>a</sup>, Johanna M. Hendriks<sup>b</sup>, Stefanos Karagiannis<sup>a</sup>, Olaf Schouten<sup>b</sup>, Radosav Vidakovic<sup>a</sup>, Marc R.H.M. van Sambeek<sup>b</sup>, Jan Klein<sup>c</sup>, Peter Noordzij<sup>c</sup>, Jeroen J. Bax<sup>d</sup> and Don Poldermans<sup>c</sup>

Coronary Artery Disease 2007, 18:483-487

## Postoperative Myocardial Ischemia

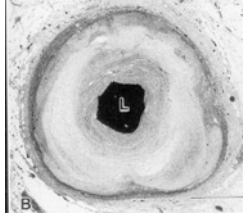


Mangano DT. NEJM, 1990

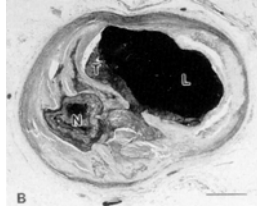
## Coronary Artery Disease Stenosis vs. Plaque Rupture?



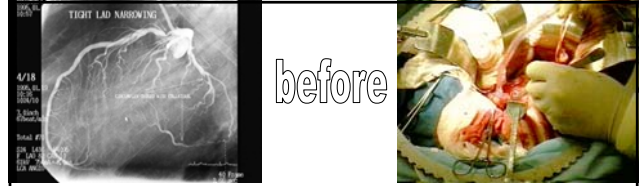
## Predominant mechanism?



Increased Demand?



Decreased Supply?



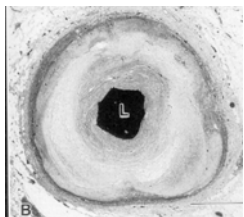
21 patients  
Postop MI or cardiac death

Poorly collateralized  
total occlusions  
~2/3

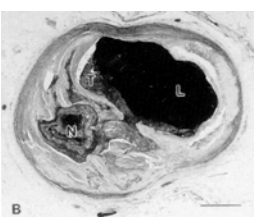
“Non-obstructive”  
lesions  
~1/3

Ellis S, et al. (Cleveland) Am J Cardiol 1996

## Predominant mechanism?

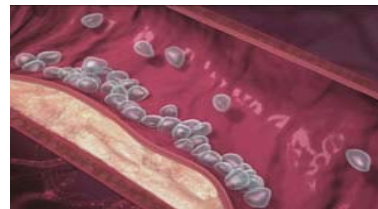


Increased Demand?  
2/3 of PMIs?



Decreased Supply?  
1/3 of PMIs?  
Plaque rupture?

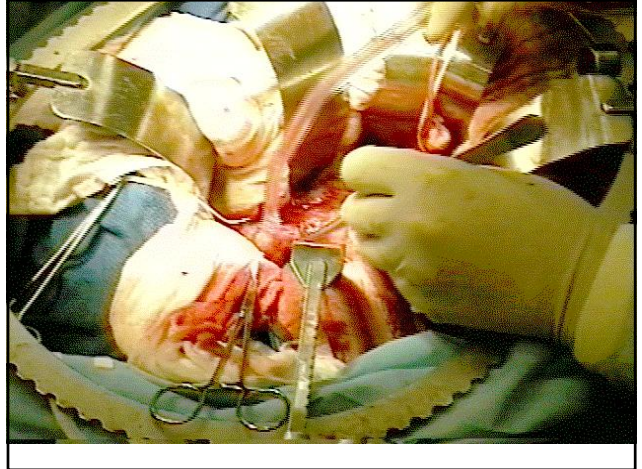
## Surgery is a hypercoagulable state



Hypercoagulability associated with  
thrombotic events

## Case study: Myocardial infarct after abdominal aortic surgery

- Coronary stents (RCA)
- Plavix (Clopidogrel)
  - blocks the platelet ADP receptor
  - prevents the binding of fibrinogen
  - Effects last for days
- Cardiac catheterization via groin
- Patient given heparin



## Stent → bleeding

- Retroperitoneal bleed
- Acidosis
- Return to the OR
- Resuscitated; hole fixed

BLOOD GASES	
MEASURED AT 37	
pH	6.99
PCO <sub>2</sub>	29
PO <sub>2</sub>	643
ELECTROLYTE	
Na <sup>+</sup>	136.9
K <sup>+</sup>	5.02
iCa <sup>++</sup>	1.39
Hct	29
CALCULATED AT 37	
HCO <sub>3</sub>	7.8
TCO <sub>2</sub>	7.3
BE	-21.2
SAT	100

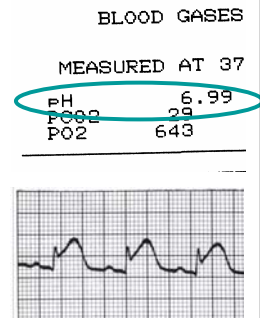


## Fresh frozen plasma + platelets



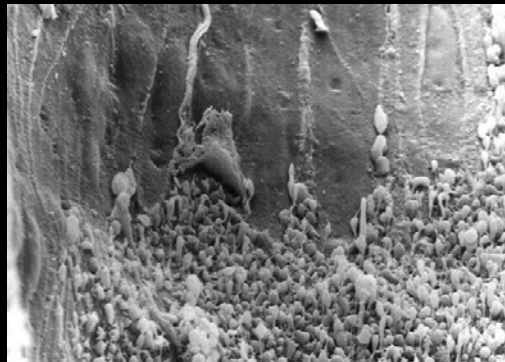
## Stent → bleeding

- Back to ICU
- RCA stents clotted  
–3 mm ST ↑ in lead II
- Back to the cath lab
- Another stent!



## Drug eluting stents (DES)

Less chronic restenosis  
More acute thrombosis (often fatal)

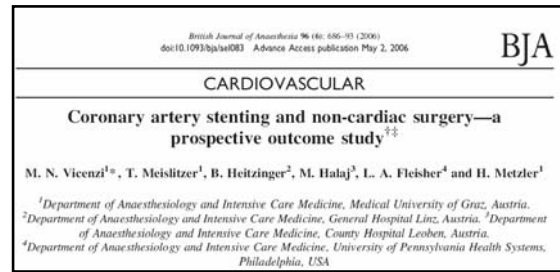


Platelets on damaged endothelium

## Clopidogrel (Plavix®)

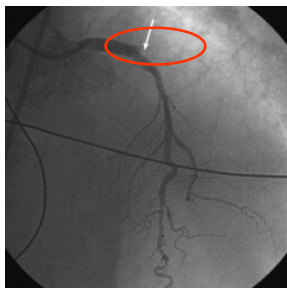
- Decreases stent thrombosis
  - ~ 50% fatal
- Increases perioperative bleeding
  - ~ 50% increase

## Trip to the cath lab postop?

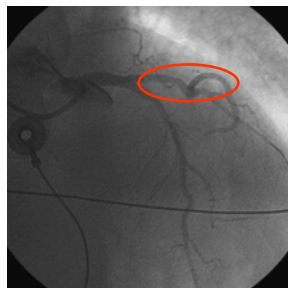


## Late Thrombosis of a Drug-eluting Stent Presenting in the Perioperative Period

Duncan G. de Souza, M.D.,\* Victor C. Baum, M.D.,† Natalie M. Ballert, M.D.‡



Cardiac cath



s/p balloon angioplasty

Anesthesiology 2007; 106:1057-9



## Surgery at center with primary PCI availability???

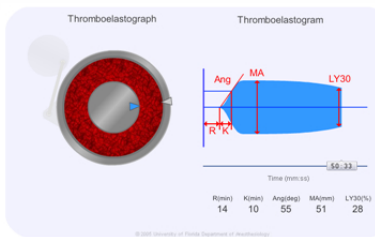
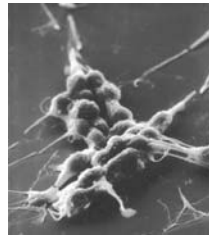


## Thromboelastography Maximum Amplitude Predicts Postoperative Thrombotic Complications Including Myocardial Infarction

Anesth Analg 2005;100:1576-83

Douglas J. McCrath, MD, Elisabetta Cerboni, Robert J. Frumento, MS, MPH, Andrew L. Hirsh, BS, and Elliott Bennett-Guerrero, MD

Department of Anesthesiology, Columbia University College of Physicians & Surgeons, New York, New York

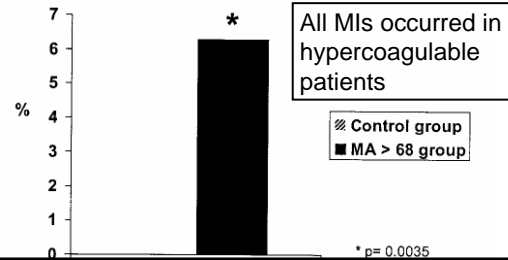


## Thromboelastography Maximum Amplitude Predicts Postoperative Thrombotic Complications Including Myocardial Infarction

Anesth Analg 2005;100:1576-83

Douglas J. McCrath, MD, Elisabetta Cerboni, Robert J. Frumento, MS, MPH, Andrew L. Hirsh, BS, and Elliott Bennett-Guerrero, MD

Department of Anesthesiology, Columbia University College of Physicians & Surgeons, New York, New York



Anesthesiology 2004, 101:1251-7

© 2004 American Society of Anesthesiologists, Inc. Lippincott Williams & Wilkins, Inc.

## Platelet Gene Polymorphisms and Cardiac Risk Assessment in Vascular Surgical Patients

Nauder Faraday, M.D., Elizabeth A. Martinez, M.D.,† Robert B. Scharf, M.S.,‡ Laura Kasch-Semenza, M.S.,§ Todd Dorman, M.D.,\* Peter J. Pronovost, M.D., Ph.D.,\* Bruce Peter, M.D.,|| Gary Gerstenblith, M.D.,# Paul F. Bray, M.D.,\*\* Lee A. Fleisher, M.D.††

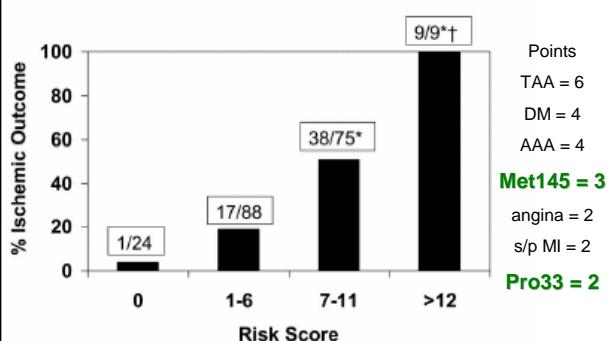
- Platelets are known to play a significant role in coronary thrombosis in nonoperative settings
- Polymorphisms in the genes encoding platelet glycoprotein (GP) IIIa and GPIIb are associated with myocardial ischemic morbidity in nonsurgical settings

Anesthesiology 2004, 101:1251-7

© 2004 American Society of Anesthesiologists, Inc. Lippincott Williams & Wilkins, Inc.

## Platelet Gene Polymorphisms and Cardiac Risk Assessment in Vascular Surgical Patients

Nauder Faraday, M.D., Elizabeth A. Martinez, M.D.,† Robert B. Scharf, M.S.,‡ Laura Kasch-Semenza, M.S.,§ Todd Dorman, M.D.,\* Peter J. Pronovost, M.D., Ph.D.,\* Bruce Peter, M.D.,|| Gary Gerstenblith, M.D.,# Paul F. Bray, M.D.,\*\* Lee A. Fleisher, M.D.††



## The Effect of Perioperative Aspirin Therapy in Peripheral Vascular Surgery: A Decision Analysis

David T. Neillipovitz, FRCP<sup>C</sup>, Gregory L. Bryson, MSc, FRCP<sup>C</sup>†, and Graham Nichol, MPH, FRCP<sup>C</sup>†

Departments of †Anesthesiology and ‡Medicine, The Ottawa Hospital, Ottawa, Ontario, Canada; and the †Clinical Epidemiology Unit, Loeb Medical Research Institute, Ottawa, Ontario, Canada

(Anesth Analg 2001;93:573-80)



Strategy	Myocardial infarction	Thrombotic CVA	Hemorrhagic CVA	Gastric bleed	Incisional bleed	All adverse events	Mortality
No aspirin	4.61%	1.69%	0.37%	0.35%	5.88%	12.90%	2.78%
Aspirin	2.71%	1.12%	0.59%	0.76%	7.71%	12.89%	2.05%

So, should every vasculopath be on statins and aspirin???

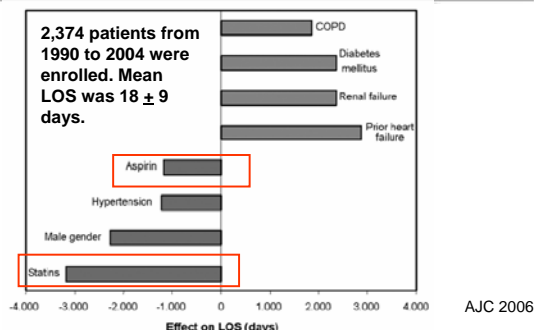
What, now we're thinking about continuing aspirin through surgery?

What about plavix (clopidogrel)?

Should we be measuring aspirin effect on platelet function?

## Influence of Cardiac Risk Factors and Medication on Length of Hospitalization in Patients Undergoing Major Vascular Surgery

Marleen A. van de Pol, MSc<sup>a</sup>, Mark van Houdenhoven, MSc<sup>a</sup>, Erwin W. Hans, PhD<sup>d</sup>, Eric Boersma, PhD<sup>e</sup>, Jeroen J. Bax, MD<sup>b</sup>, Harm H.H. Feringa, MD<sup>a</sup>, Olaf Schouten, MD<sup>f</sup>, Marc R.H.M. van Sambeek, MD<sup>c</sup>, and Don Poldermans, MD<sup>a\*</sup>



## The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 DECEMBER 30, 2004 VOL. 351 NO. 27

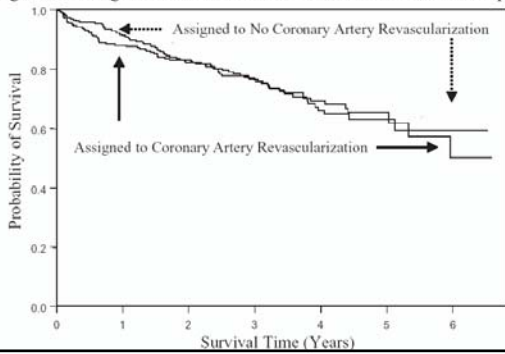
### Coronary-Artery Revascularization before Elective Major Vascular Surgery

Edward O. McFall, M.D., Ph.D., Herbert B. Ward, M.D., Ph.D., Thomas E. Moritz, M.S., Steven Goldman, M.D., William C. Krupski, M.D., \* Fred Littooy, M.D., Gordon Pierpont, M.D., Steve Santilli, M.D., Joseph Rapp, M.D., Brack Hattler, M.D., Kendrick Shunk, M.D., Ph.D., Connie Jaenicke, R.N., B.S.N., Lizy Thottapurathu, M.S., Nancy Ellis, M.S., Domenic J. Reda, Ph.D., and William G. Henderson, Ph.D.

- The "CARP" study

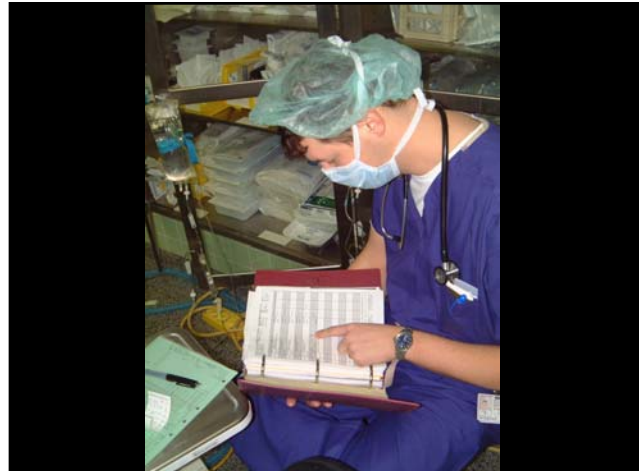
## No difference in outcome!

Figure 2: Long-Term Survival in the Two Randomized Groups



## Do your patients get such good medical Rx?

	Revascularization (N=225)	No Revascularization (N=237)	P- Value
<b>Perioperative Medications</b>			
Beta-adrenergic blockers (%)	188 (83.9)	204 (86.4)	0.45
Aspirin (%)	150 (76.1)	147 (70.0)	0.16
Statins (%)	121 (53.5)	122 (54.0)	0.93
Heparin (%)	209 (93.7)	219 (93.2)	0.82
Nitroglycerine (IV) (%)	63 (28.4)	87 (37.0)	0.05



**Multivariable Predictors of Postoperative Cardiac Adverse Events after General and Vascular Surgery: Results from the Patient Safety in Surgery Study** J Am Coll Surg 2007;204: 1199

Daniel L Davenport, PhD, Victor A Ferraris, MD, PhD, FACS, Patrick Hosokawa, MS, William G Henderson, PhD, Shukri F Khuri, MD, FACS, Robert M Mentzer Jr, MD, FACS

- 2 outcomes:
  - Transmural (Q wave) MI
  - Cardiac arrest
- N ~ 180,000!
  - Prospective data collection!

**Multivariable Predictors of Postoperative Cardiac Adverse Events after General and Vascular Surgery: Results from the Patient Safety in Surgery Study** J Am Coll Surg 2007;204: 1199

Daniel L Davenport, PhD, Victor A Ferraris, MD, PhD, FACS, Patrick Hosokawa, MS, William G Henderson, PhD, Shukri F Khuri, MD, FACS, Robert M Mentzer Jr, MD, FACS

What factors best predict severe cardiac complications?

**Table 4.** Independent Predictors of Cardiac Adverse Events and Associated Risk Points

Predictor	Odds ratio	95% CI
ASA physical status class		
4-5 versus 1-2	5.797	4.264-7.882
3 versus 1-2	3.309	2.488-4.401
Work RVU class of most complex procedure		
> 17 versus < 10	2.980	2.324-3.821
10-17 versus < 10	1.837	1.450-2.328
Emergency	1.713	1.463-2.006

- ASA classification
- Complex surgery
- Emergency surgery

J Am Coll Surg 2007;204: 1199

Predictor	Odds ratio
ASA physical status class	
4-5 versus 1-2	5.797
3 versus 1-2	3.309

- ASA classification!

J Am Coll Surg 2007;204: 1199

Preoperative creatinine $\geq$ 1.5 mg/dL	1.735	1.521–1.978
Age (y)		
40–65 versus < 40	2.737	1.483–5.051
> 65 versus < 40	4.618	2.503–8.520
Preoperative sepsis	1.561	1.271–1.917
Bleeding disorders	1.473	1.217–1.783
Weight loss	1.605	1.334–1.932
Congestive heart failure < 30 d before operation	1.593	1.300–1.953

J Am Coll Surg 2007;204:1199

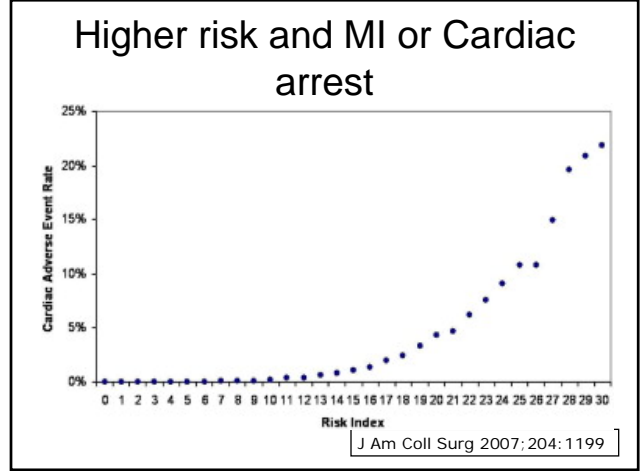
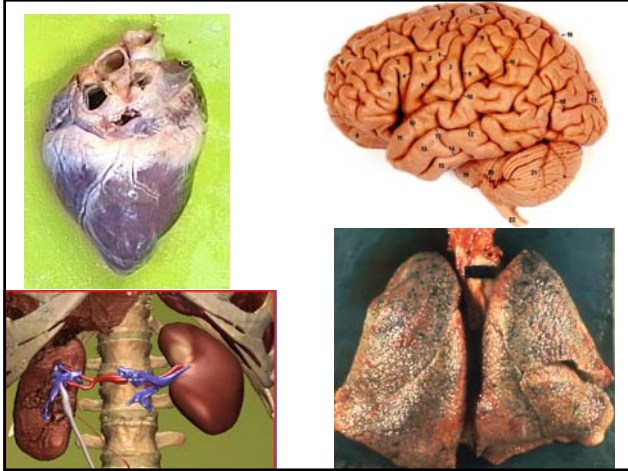
Type of operation		
Mouth, palate versus endocrine	3.473	1.104–10.924
Thoracoabdominal aneurysm versus endocrine	3.365	1.156–9.795
Peripheral aneurysm versus endocrine	3.050	1.084–8.582
Stomach, intestines versus endocrine	3.193	1.176–8.667
Respiratory and hemic versus endocrine	3.207	1.065–9.659
Integumentary versus endocrine	3.054	1.096–8.508
Hernia versus endocrine	1.451	0.509–4.138

J Am Coll Surg 2007;204:1199

WBC count th/cumm		
Preoperative (< 2.5 versus 2.5–10)	1.698	0.873–3.304
Preoperative (> 10 versus 2.5–10)	1.377	1.199–1.581
Preoperative platelet count $\leq$ 150,000/cumm	1.444	1.219–1.710
Impaired sensorium	1.352	1.076–1.698
Dyspnea (yes versus no)	1.218	1.064–1.395
CVA/stroke with neurologic deficit	1.304	1.083–1.571
Ascites	1.503	1.133–1.992
Wound class		
Contaminated versus clean	1.231	0.963–1.573
Clean/contaminated versus clean	1.326	1.108–1.586
Infected versus clean	1.054	0.817–1.360
Preoperative albumin ( $\leq$ 3.5 versus > 3.5 g/dL)	1.180	1.028–1.356
Gender (male versus female)	1.256	1.031–1.529
Specialty (vascular versus general)	1.365	1.017–1.834

J Am Coll Surg 2007;204:1199

None of this relies  
on stress tests or  
coronary history!



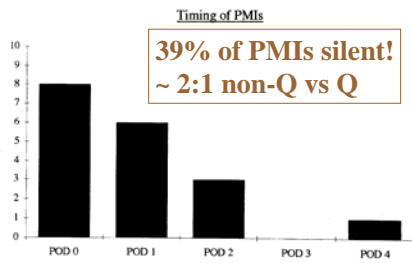
### Laboratory testing of the high-risk and/or unstable patient

This block contains three images related to laboratory testing. Top left: A standard 12-lead ECG strip. Bottom left: A clear plastic IV bag containing a red liquid. Right: A patient monitor displaying multiple vital signs and waveforms.

### Biomarkers to predict risk and outcome

This block contains one image showing a medical professional in blue scrubs and gloves drawing blood from a patient's arm into a test tube.

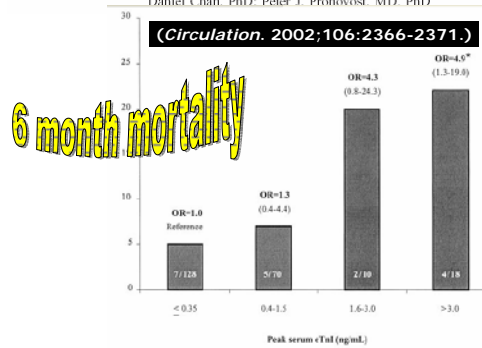
## When does POMI occur?



Badner et al. Anesth 1998

## Cardiac Troponin I Predicts Short-Term Mortality in Vascular Surgery Patients

Lauren J. Kim, MPH; Elizabeth A. Martinez, MD; Nauder Faraday, MD; Todd Dorman, MD; Lee A. Fleisher, MD; Bruce A. Perler, MD; G. Melville Williams, MD; Daniel Chan, PhD; Peter J. Pronovost, MD, PhD



## Intense Cardiac Troponin Surveillance for Long-Term Benefits is Cost-Effective in Patients Undergoing Open Abdominal Aortic Surgery: A Decision Analysis Model

Srinivas Mantha, MD\*  
Joseph Foss, MD†  
John E. Ellis, MD‡  
Michael F. Roizen, MD†

Anesth Analg 2007;105:000-000

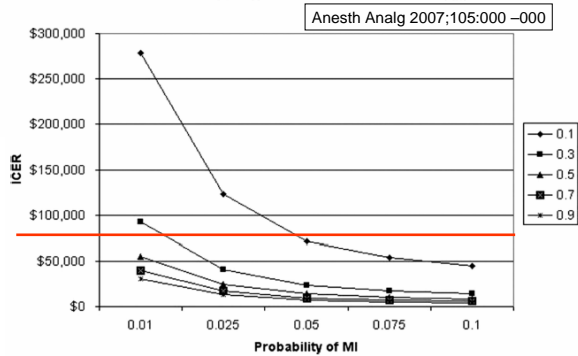
## Intense Cardiac Troponin Surveillance for Long-Term Benefits is Cost-Effective in Patients Undergoing Open Abdominal Aortic Surgery: A Decision Analysis Model

Srinivas Mantha, MD\*  
Joseph Foss, MD†  
John E. Ellis, MD‡  
Michael F. Roizen, MD†

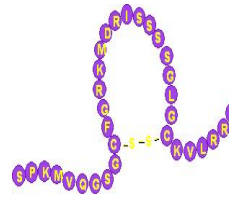
- Aggressive surveillance →
- ICU admission and aggressive beta blockade, monitoring...
- Aspirin, statins, euglycemia, PCI??

Anesth Analg 2007;105:000-000

**Intense Cardiac Troponin Surveillance for Long-Term Benefits is Cost-Effective in Patients Undergoing Open Abdominal Aortic Surgery: A Decision Analysis Model**



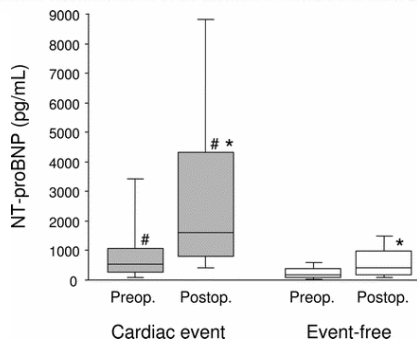
**B type Natriuretic Peptide (BNP)**



- Natriuretic peptides help regulate salt and water balance
- Levels increase as heart failure symptoms worsen.
- BNP levels are used to help diagnose CHF.

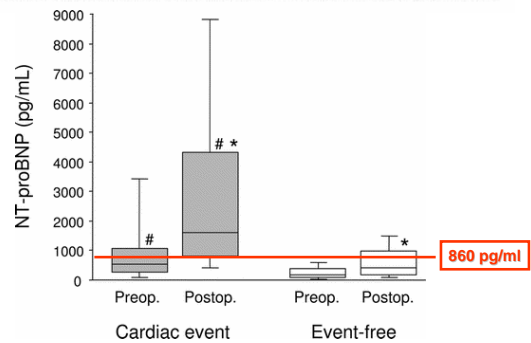
**N-Terminal Pro-brain Natriuretic Peptide Identifies Patients at High Risk for Adverse Cardiac Outcome after Vascular Surgery**

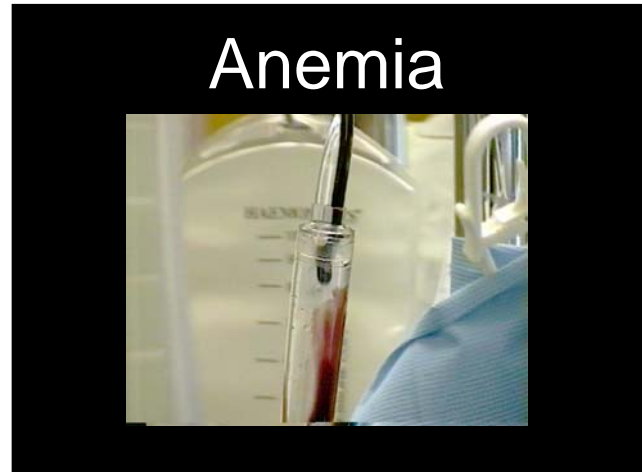
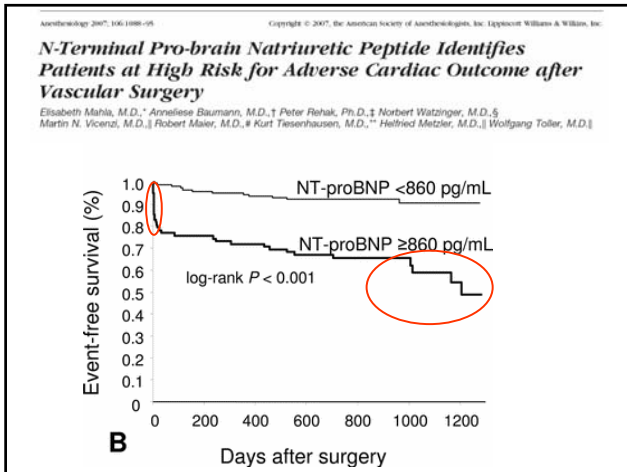
Elisabeth Mahla, M.D.,\* Anneliese Baumann, M.D.,† Peter Rehak, Ph.D.,‡ Norbert Watzinger, M.D.,§ Martin N. Vicenzi, M.D.,|| Robert Maier, M.D.,# Kurt Tesenhausen, M.D.,\*\* Helfried Metzler, M.D.,|| Wolfgang Toller, M.D.||



**N-Terminal Pro-brain Natriuretic Peptide Identifies Patients at High Risk for Adverse Cardiac Outcome after Vascular Surgery**

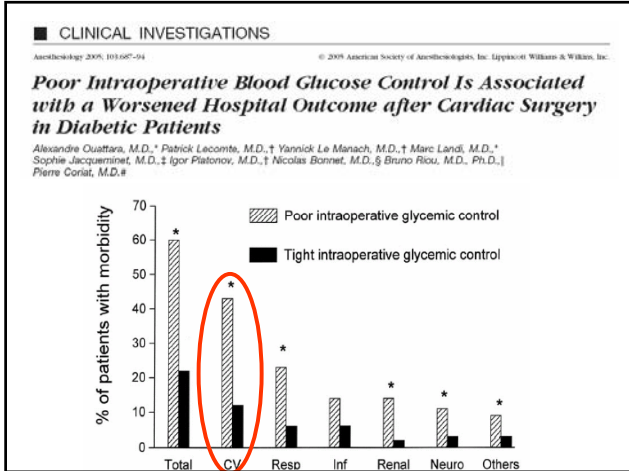
Elisabeth Mahla, M.D.,\* Anneliese Baumann, M.D.,† Peter Rehak, Ph.D.,‡ Norbert Watzinger, M.D.,§ Martin N. Vicenzi, M.D.,|| Robert Maier, M.D.,# Kurt Tesenhausen, M.D.,\*\* Helfried Metzler, M.D.,|| Wolfgang Toller, M.D.||





- ## Blood is bad
- Anemia is bad
  - Blood loss is bad
  - Blood transfusion is bad
    - Old blood particularly bad
  - I'm still confused!





- Beta blockade 2007**
- Earlier trials show protection
  - More recent trials questionable
  - Await POISE (n=10,000)
  - Not everyone benefits
    - Genetic predisposition

Journal of the American College of Cardiology  
© 2006 by the American College of Cardiology Foundation  
Published by Elsevier Inc.

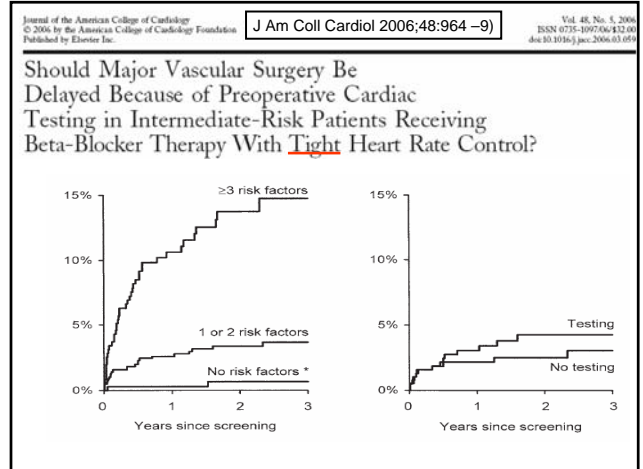
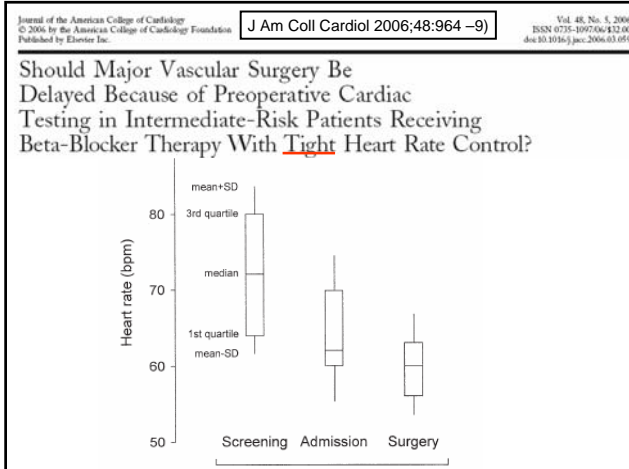
J Am Coll Cardiol 2006;48:964-9

Vol. 48, No. 5, 2006  
ISSN 0735-1097/06/48:00  
doi:10.1016/j.jacc.2006.03.059

**Should Major Vascular Surgery Be Delayed Because of Preoperative Cardiac Testing in Intermediate-Risk Patients Receiving Beta-Blocker Therapy With Tight Heart Rate Control?**

Don Poldermans, MD, PhD,\* Jeroen J. Bax, MD, PhD,† Olaf Schouten, MD,‡ Aleksandar N. Neskovik, MD, PhD,§ Bernard Paclinek, MD, PhD,|| Guido Rocci, MD, PhD,¶ Laura van Dortmont, MD, PhD,‡ Anai E. S. Durazzo, MD, PhD,\*\* Louis L. M. van de Ven, MD, PhD,†† Marc R. H. M. van Sambeek, MD, PhD,‡‡ Miklos D. Kertai, MD, PhD,‡‡ Eric Boersma, PhD,‡‡ for the Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echo Study Group

Rotterdam, Leiden, Schiedam, and Amsterdam, the Netherlands; Belgrade, Serbia and Montenegro; Antwerp, Belgium; Bologna, Italy; and São Paulo, Brazil



Aggressive beta blockade at least as good as stress test algorithm

A1439

October 16, 2007  
9:00 AM - 10:30 AM  
Room Room 120

#### An Update on the Beta Blocker Meta Analysis: Heart Rate Control Reduces Post-Operative MI

Farhan Husain, M.D., Scott Beattie, M.D., F.R.C.P.C., Duminda Wijeyesundera, M.D., F.R.C.P.C., Keyvan Karkouti, M.D., F.R.C.P.C., Stuart McCluskey, M.D., F.R.C.P.C.  
Anesthesia, Toronto General Hospital, Toronto, Ontario, Canada

- Short acting beta-blockers were not protective against perioperative MI  
– RR 1.08; 95% CI 0.74-1.49; P=0.69
- Longer acting and continuous infusion beta-blockers were  
– RR 0.20; 95% CI 0.06-0.64; P=0.007
- **Attaining low heart rates decreased MI**

Does the “average”  
anesthesiologist beta  
block to HR = 60?

**No!**

**Predictors of Perioperative  $\beta$ -Blockade Use in Vascular Surgery: A Mail Survey of United States Anesthesiologists**

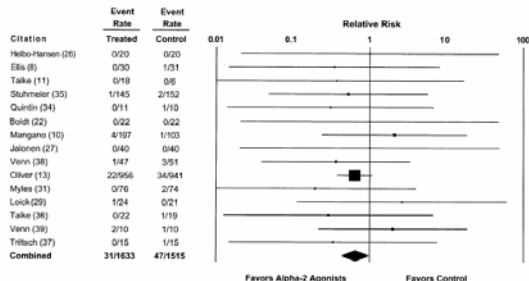
John E. Ellis, MD,\* Avery Tung, MD,\* Hubert Lee, BA,† and Kristen Kasza, MS‡

**Table 5. “How High Would the Heart Rate be to Cause You to Give a  $\beta$ -Blocker?”**

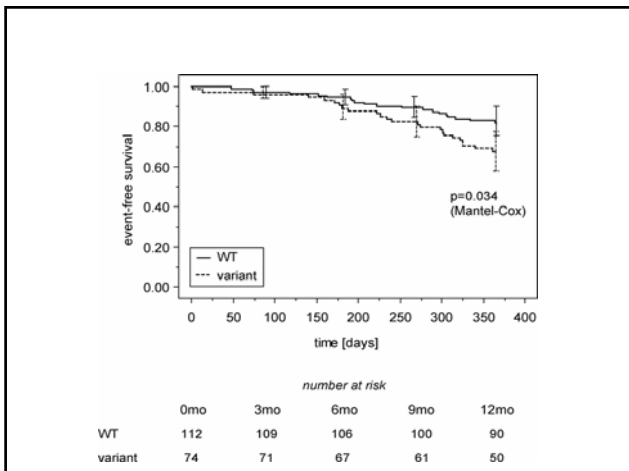
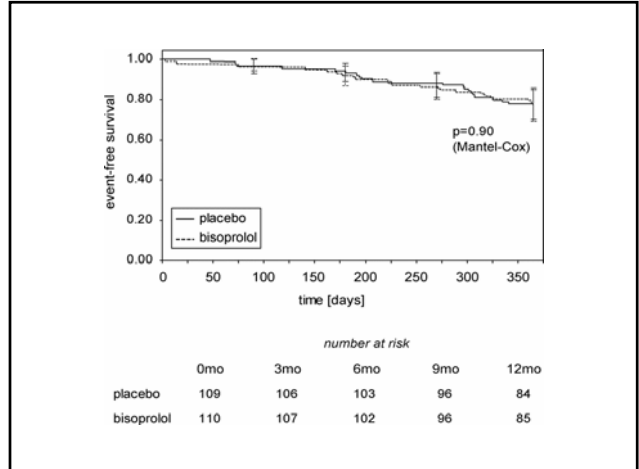
	N	Mean	SD	Median	Minimum-Maximum
Preoperative	412	90.3	13.1	90	50-200
Intraoperative	416	90.3	13.2	90	60-125
Postoperative	413	89.6	12.8	90	50-120

**Alpha-2 Adrenergic Agonists to Prevent Perioperative Cardiovascular Complications: A Meta-analysis**

Duminda N. Wijeyesundera, MD, Jennifer S. Naik, MD, W. Scott Beattie, MD, PhD



**Genetics and response to beta blockade**



**Inflammatory Gene Polymorphisms and Risk of Postoperative Myocardial Infarction After Cardiac Surgery**

M.V. Podgoreanu, MD; W.D. White, MPH; R.W. Morris, PhD; J.P. Mathew, MD; M. Stafford-Smith, MD; I.J. Welsby, MD; H.P. Grocott, MD; C.A. Milano, MD; M.F. Newman, MD; D.A. Schwinn, MD;  
 Perioperative Genetics and Safety Outcomes Study (PEGASUS) Investigative Team

- 3 polymorphisms were independent predictors of PMI
  - proinflammatory cytokine interleukin 6
  - intercellular adhesion molecule-1 (ICAM1)
  - E-selectin

(Circulation. 2006;114[suppl I]:I-275-I-281.)

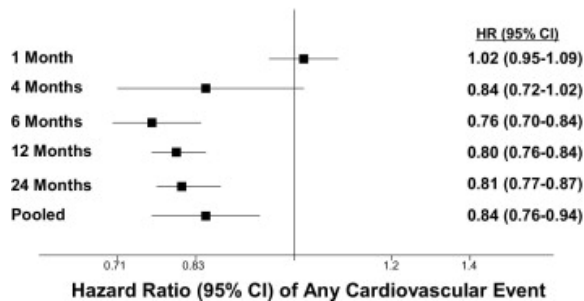
## Statins 2007

- Small randomized trials show benefit
- Many retrospective studies show benefit
- Many benefits besides lipid lowering
  - Reduced inflammations
  - NOS
- Risks of rhabdomyolysis very low

## Statins 2007

- Should be continued perioperatively
- Should start if PMI develops
- Start acutely routinely perioperatively in high risk patients ??

## Statins after ACS



Hulten, E. et al. Arch Intern Med 2006;166:1814-1821.

ARCHIVES OF  
INTERNAL MEDICINE

Copyright restrictions may apply.

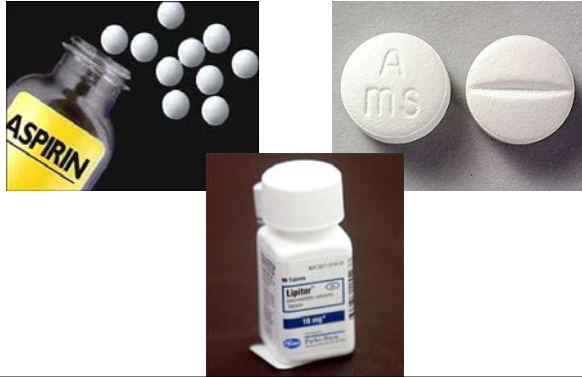
PERSPECTIVE

### Cardiac Events in Patients Undergoing Noncardiac Surgery: Shifting the Paradigm from Noninvasive Risk Stratification to Therapy

Paul A. Grayburn, MD, and L. David Hillix, MD

In short, the paradigm is shifting from predicting which patient is at high risk for having a perioperative cardiac event to minimizing the likelihood of such an event with specific perioperative pharmacologic therapy.

## “Breakfast of Champions!”



## “Specific perioperative pharmacologic therapy includes...”

- Volatile anesthetics
  - “Better than high dose opiates?”
  - Combination is best
- Thoracic epidural local anesthetics
  - “Can’t I just thread a lumbar catheter up?”

## The future?

Personalized (genetic)  
testing and therapy

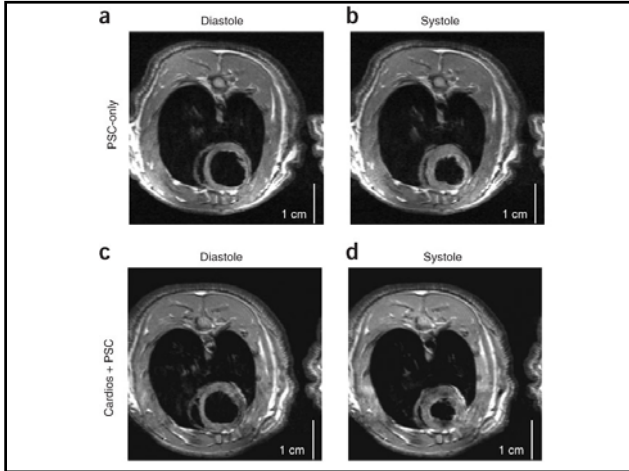
Stem cells to repair  
injured myocardium?

nature  
biotechnology

Cardiomyocytes derived from human embryonic stem cells in pro-survival factors enhance function of infarcted rat hearts

Michael A Laflamme<sup>1,2,6</sup>, Kent Y Chen<sup>1-3,6</sup>, Anna V Naumova<sup>1,4</sup>, Veronica Muskheli<sup>1,2</sup>, James A Fugate<sup>1,2</sup>, Sarah K Dupras<sup>1,2</sup>, Hans Reinecke<sup>1,2</sup>, Chunhui Xu<sup>5</sup>, Mohammad Hassanipour<sup>5</sup>, Shailaja Police<sup>5</sup>, Chris O’Sullivan<sup>5</sup>, Lila Collins<sup>5</sup>, Yinrong Chen<sup>5</sup>, Elina Minami<sup>1,3</sup>, Edward A Gill<sup>3</sup>, Shuichi Ueno<sup>1,2</sup>, Chun Yuan<sup>1,4</sup>, Joseph Gold<sup>6</sup> & Charles E Murry<sup>1,2</sup>

NATURE BIOTECHNOLOGY VOLUME 25 NUMBER 9 SEPTEMBER 2007



Slides available  
(PDF)

[johnellis1700@gmail.com](mailto:johnellis1700@gmail.com)