Achieving Excellence in the Diagnosis of Acute Cardiovascular Events
Measurement and Improvement Considerations for Diagnostic Accuracy

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- Co-Author of ACC/AHA 2013 Guideline for the Management of ST-Elevation Myocardial Infarction
- Co-Author of 2015 ACC/AHA/SCAI focused update on primary percutaneous coronary intervention for patients with ST-elevation myocardial Infarction
- Co-Author 2014 AHA/ACC Guideline for the Management of Patients With Non–ST-Elevation Acute Coronary Syndromes (NSTE-ACS)
- Adjunct Faculty, Jefferson College of Population Health
- Faculty, Rush Medical College
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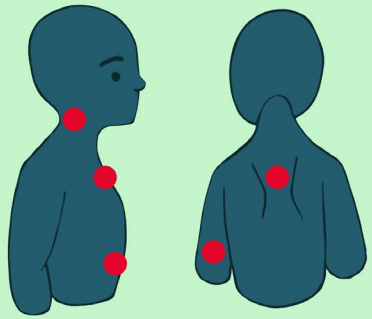
- Past President, American College of Medical Quality (ACMQ)

National Academy of Medicine Virtual Workshop, Friday, April 23rd, 2021

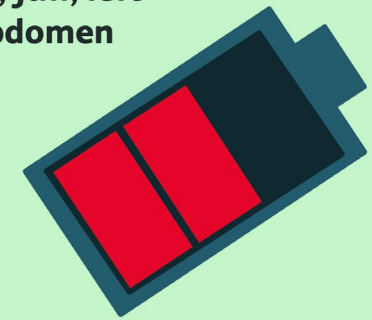
Symptoms of ST-Segment Elevation Myocardial Infarction (STEMI)



Pain around the shoulder blades, arm, chest, jaw, left arm, or upper abdomen

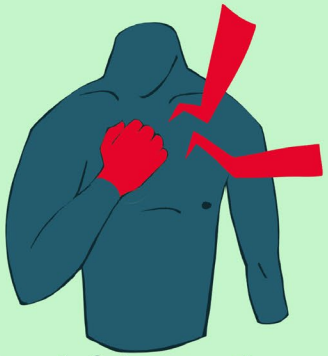
Nausea and vomiting

Discomfort or tightness in the neck or arm



Fatigue or sudden exhaustion

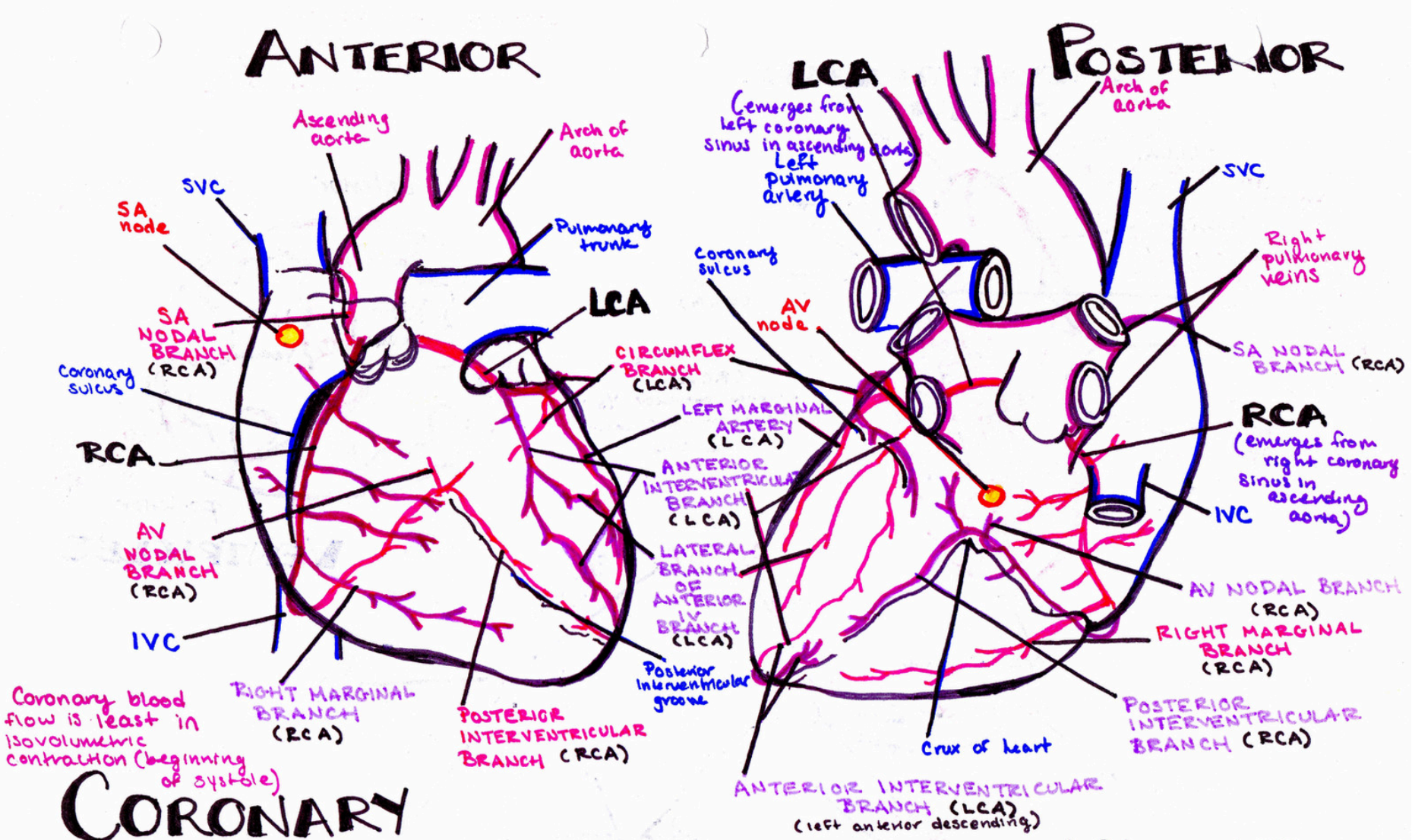
Indigestion or heartburn



A painful sensation described as having a "clenched fist in the chest"

verywell

DISCLAIMER:
Not designed by a human engineer and/or a computer



Coronary blood flow is least in isovolumetric contraction (beginning of systole)

CORONARY CIRCULATION

CORONARY ARTERIES FILL DURING DIASTOLE WHEN AORTIC VALVE IS CLOSED

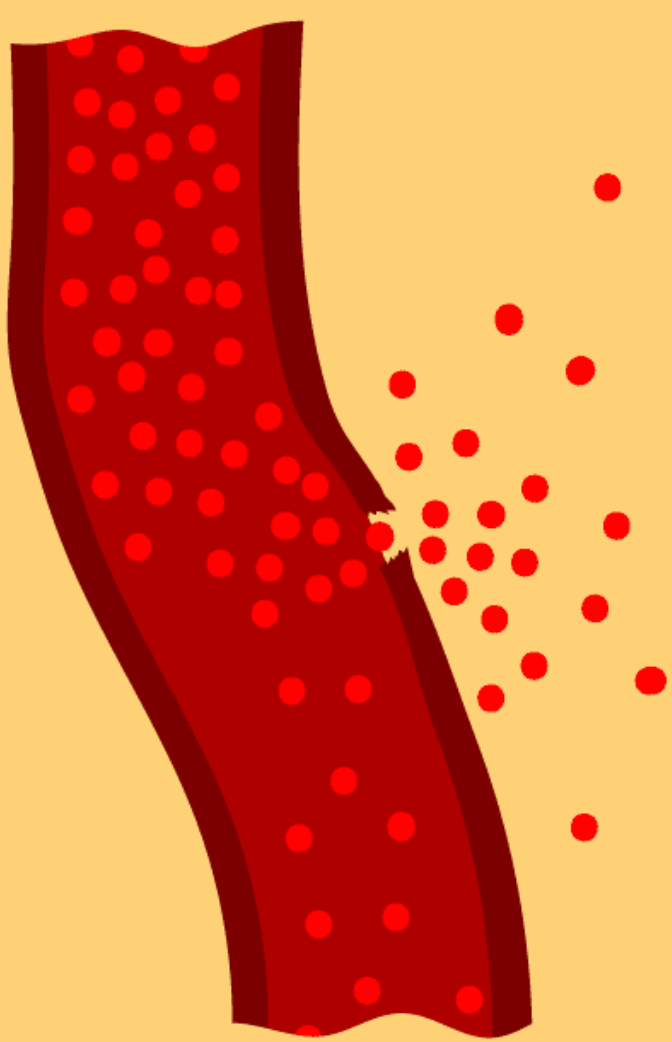
RCA supplies:

- right atrium
- right ventricle
- diaphragmatic surface of left ventricle
- posterior 1/3 of IV septum
- SA node (60% of people)
- AV node (80% of people)

coronary blood flow (mL/min) is determined by pumping action (stroke work x HR) of the ♡ and is affected by all factors affecting cardiac output

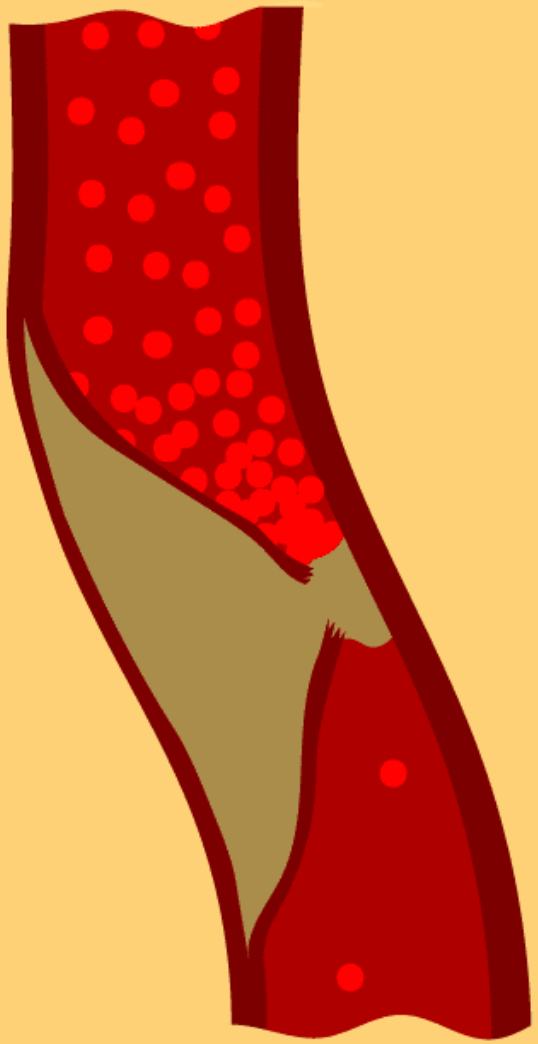
LCA supplies:

- left atrium
- most of left ventricle
- part of right ventricle
- anterior 2/3 of IV septum, including AV bundle
- SA node (40% of people)



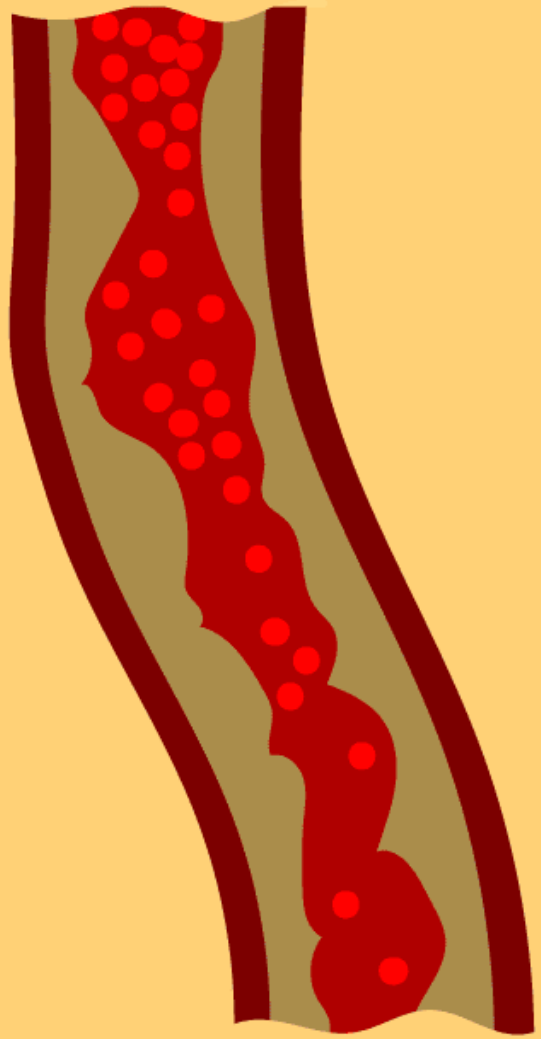
Unstable angina

- partial rupture of an artery
- does not cause permanent damage to the heart



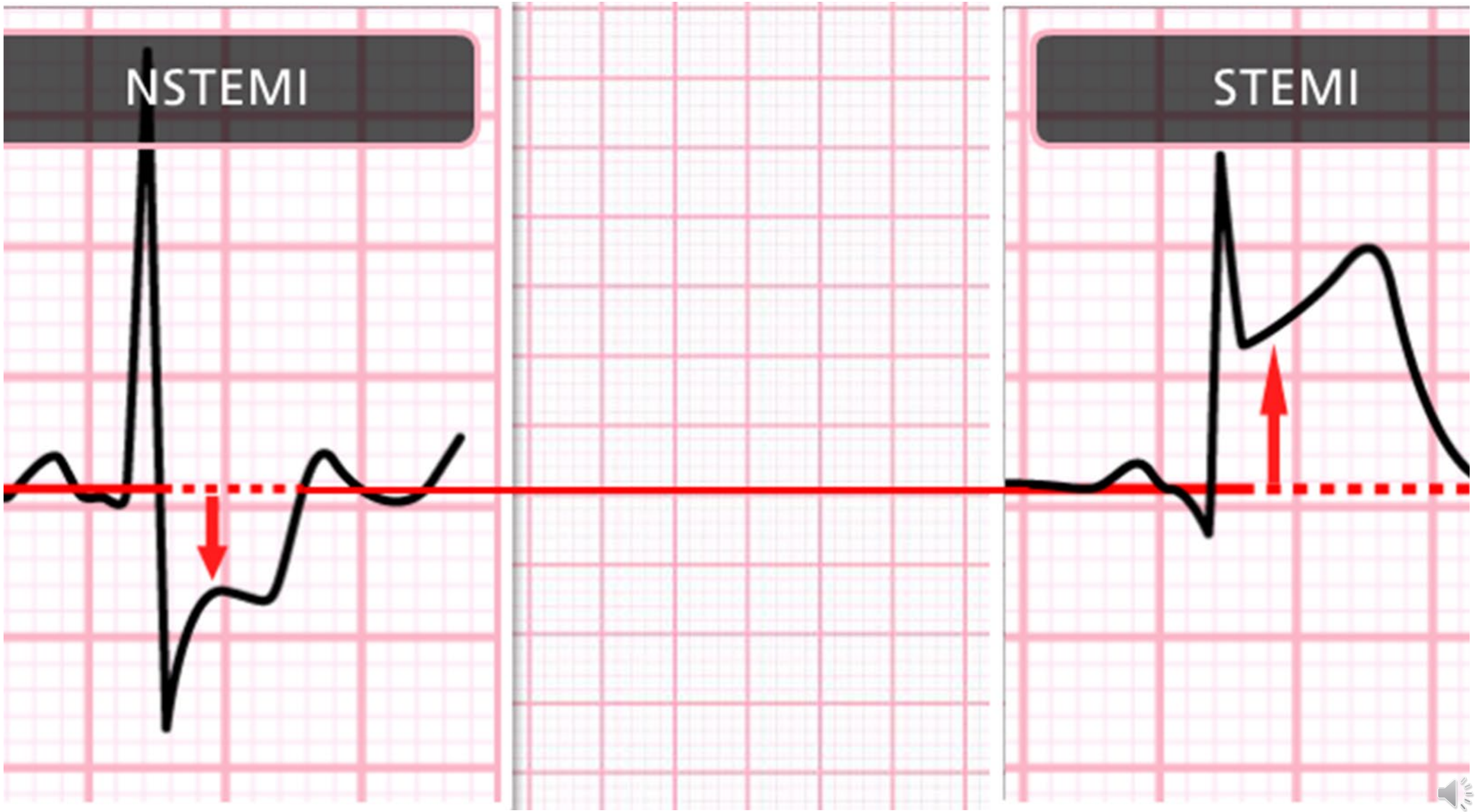
STEMI

- "classic" heart attack
- causes extensive heart damage



NSTEMI

- intermediate form of ACS
- causes less extensive damage to the heart


NSTEMI
STEMI

Circulation. 2007;116:217–230
https://doi.org/10.1161/CIRCULATIONAHA.107.184043

Call 9-1-1
Call fast

Onset of symptoms of STEMI

9-1-1 EMS Dispatch

EMS on-scene
- Encourage 12-lead ECGs
- Consider prehospital fibrinolytic if capable and EMS-to-needle within 30 min

EMS Triage Plan

Hospital fibrinolysis:
Door-to-Needle within 30 min

Not PCI capable

Inter-Hospital Transfer

PCI capable

Goals

Patient	*Dispatch*	*EMS on scene*	*EMS transport*	
5 min after symptom onset	1 min	Within 8 min	Prehospital fibrinolysis: EMS-to-Needle within 30 min	*EMS transport:* EMS-to-Balloon within 90 min *Patient self-transport:* Hospital Door-to-Balloon within 90 min

Total ischemic time: Within 120 min*

*Golden Hour = First 60 minutes

“Time is Myocardium”

“Time is Myocardium”

Code STEMI Tracking, All STEMI Patients entering ED 01/02/2009 through 2/18/09

							Emergency Department			Team Activation			Cath Lab						
January 2009																			
Pt Seq#	**Door To Balloon Time**	Mode of Arrival	ED Arrival Date/Time			Pre Hosp ECG	**Door to ECG**	**ECG to Dx**	**Dx to Page** *	**Page to CB** *	**CB to Arrival** *	**Arrival to pt on table**	**Table to pt ready**	Prep to sheath in	Sheath to Dx comp	**Dx compl to wire**	**Wire to reperf / infl**	Table to reperfusion	Inflation Date/Time
GOAL:	**90 Min**						**8 Min**	**1 Min**	**2 Min**	**5 Min**	**20 Min**	**25 Min**	**5 Min**	4 Min	12 Min	**3 Min**	**5 Min**		
1 0168	83	BLS	Fri	1/2/09	7:41 am		21	1	3	1	6	20	7	8	7	8	1	31	1/2/09 9:04 am
2 1522	74	AMB	Fri	1/2/09	6:06 pm		13	4	0	2	26	0	10	7	9	2	1	29	1/2/09 7:20 pm
3 0473	91	AIR	Sat	1/3/09	5:12 pm		2	0	6	5	25	20	6	3	13	10	1	33	1/3/09 6:43 pm
4 1489	68	MICU	Fri	1/9/09	3:35 pm	Y							2	1	12	19	6	40	1/9/09 4:43 pm
5 0024	75	MICU	Mon	1/12/09	2:50 am	Y	2	0	-6	9	7	27	12	0	7	14	3	36	1/12/09 4:05 am
6 0627	62	MICU	Sat	1/17/09	5:11 pm	Y	-16	18	-8	3	28	13	6	1	8	8	1	24	1/17/09 6:13 pm
7 0135	56	AIR	Fri	1/23/09	7:30 am		9	-9	4	0	9	14	7	6	7	7	2	29	1/23/09 8:26 am
8 1964	84	AMB	Mon	1/26/09	11:56 pm		15	2	2	1	-4	29	10	5	6	14	4	39	1/27/09 1:20 am
9 0520	67	BLS	Sat	1/31/09	2:33 pm	Y	7	-38	6	2	35	20	11	0	14	7	3	35	1/31/09 3:40 pm
Avg D2B Jan-09 = 73 Min Median = 74Min							7	-3	1	6	17	18	8	3	9	10	2	33	

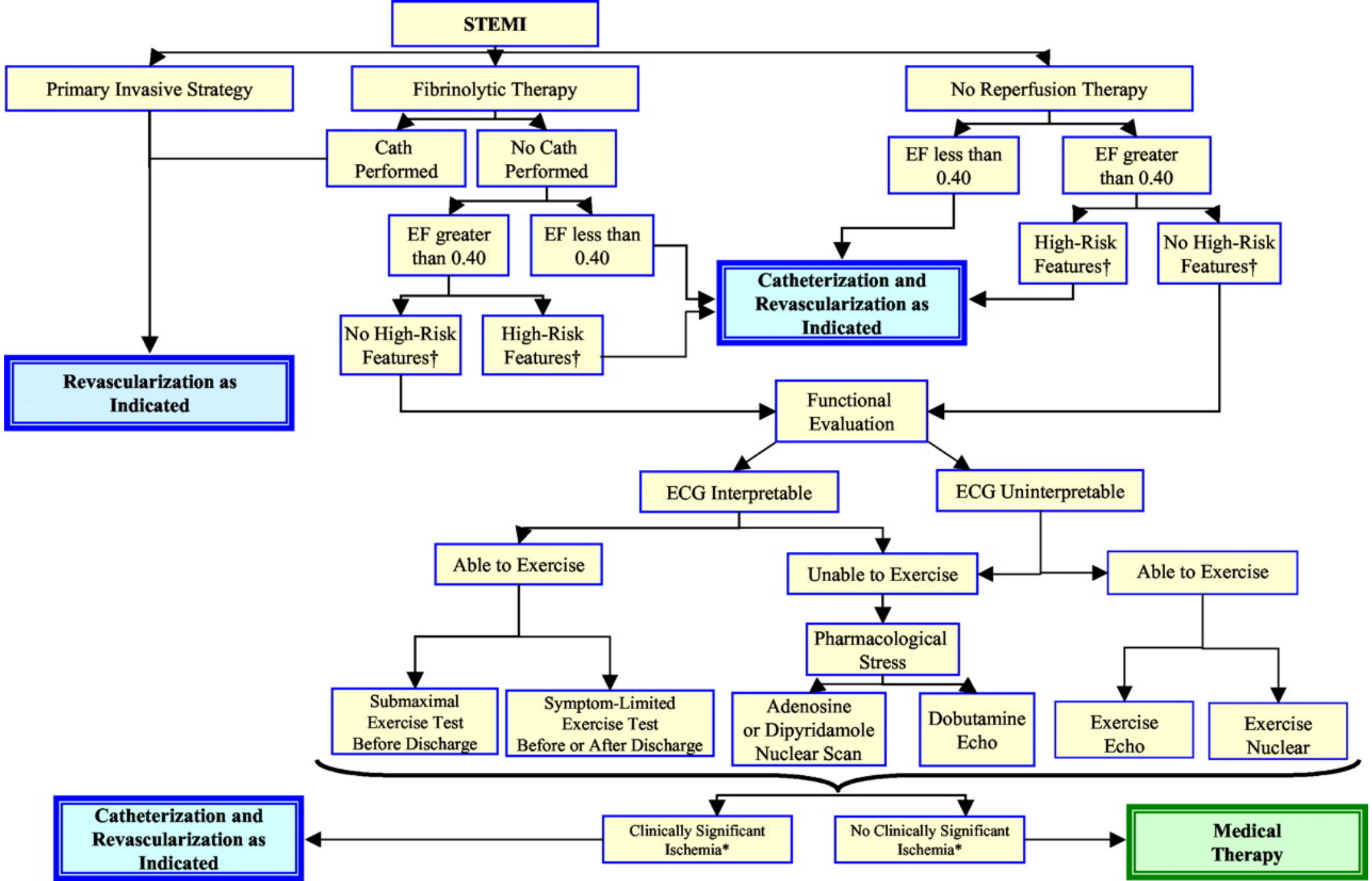

STEMI
Primary Invasive Strategy
Fibrinolytic Therapy
No Reperfusion Therapy
Cath Performed
No Cath Performed
EF less than 0.40
EF greater than 0.40
EF greater than 0.40
EF less than 0.40
High-Risk Features†
No High-Risk Features†
Catheterization and Revascularization as Indicated
No High-Risk Features†
High-Risk Features†
Revascularization as Indicated
Functional Evaluation
ECG Interpretable
ECG Uninterpretable
Able to Exercise
Unable to Exercise
Able to Exercise
Pharmacological Stress
Submaximal Exercise Test Before Discharge
Symptom-Limited Exercise Test Before or After Discharge
Adenosine or Dipyridamole Nuclear Scan
Dobutamine Echo
Exercise Echo
Exercise Nuclear
Catheterization and Revascularization as Indicated
Clinically Significant Ischemia*
No Clinically Significant Ischemia*
Medical Therapy

Table 1. Hospital-Based Strategies Associated with Shorter Door-to-Balloon Time and Potential Tools to Implement Them.*

Hospital-Based Strategy	Description	Potential Tools
Prehospital ECG and activation	Greater use of prehospital ECGs by emergency medical services, with early activation of catheterization laboratory en route	Prehospital ECG policy Clinical pathway (ECG in emergency department) Guidelines for rapid assessment Protocol for obtaining prompt ECG
Emergency department bypass	Direct transfer to the catheterization laboratory by emergency medical services using prehospital ECGs	Prehospital ECG policy Guidelines for direct activation of catheterization laboratory
Process for triaging patients and rapidly obtaining ECG in the emergency department	Establishment of physical space and guidelines in the emergency department for obtaining ECGs during triage evaluations	Dedicated personnel and private area for obtaining ECG in triage
Emergency department activation of the catheterization laboratory	Activation of the catheterization laboratory team by emergency medicine physicians without routine cardiology consultation	Activation policy
Single-call activation	Establishment of a single-call system for activating the entire catheterization laboratory team	Alert system
Rapid arrival of PCI team at hospital	Establishment of the expectation that team members will be available to receive the patient 20–30 min after being paged	Staff policy
Process of performing PCI	Clearance of elective cases during routine work hours; preparation of angioplasty tables during off-hours; clear demarcation of roles for technical and nursing staff	Guidelines for work flow during the day and maintaining availability of standardized equipment during off-hours Protocol for typical diagnostic and PCI approaches
Prompt data feedback	Routine data monitoring of performance with provision of prompt feedback	Time-entry form E-mail team members door-to-balloon times after procedure
Senior management commitment	Organizational environment with strong support by senior management as well as a culture that fosters and sustains organizational change directed at improving door-to-balloon time	Leadership development program
Team-based approach	Emphasis on a team-based approach that provides seamless care from arrival of ambulance to balloon inflation before reperfusion — limit handoffs, one team; organizational support for continuous quality improvement	Tutorial on continuous quality improvement Team training program

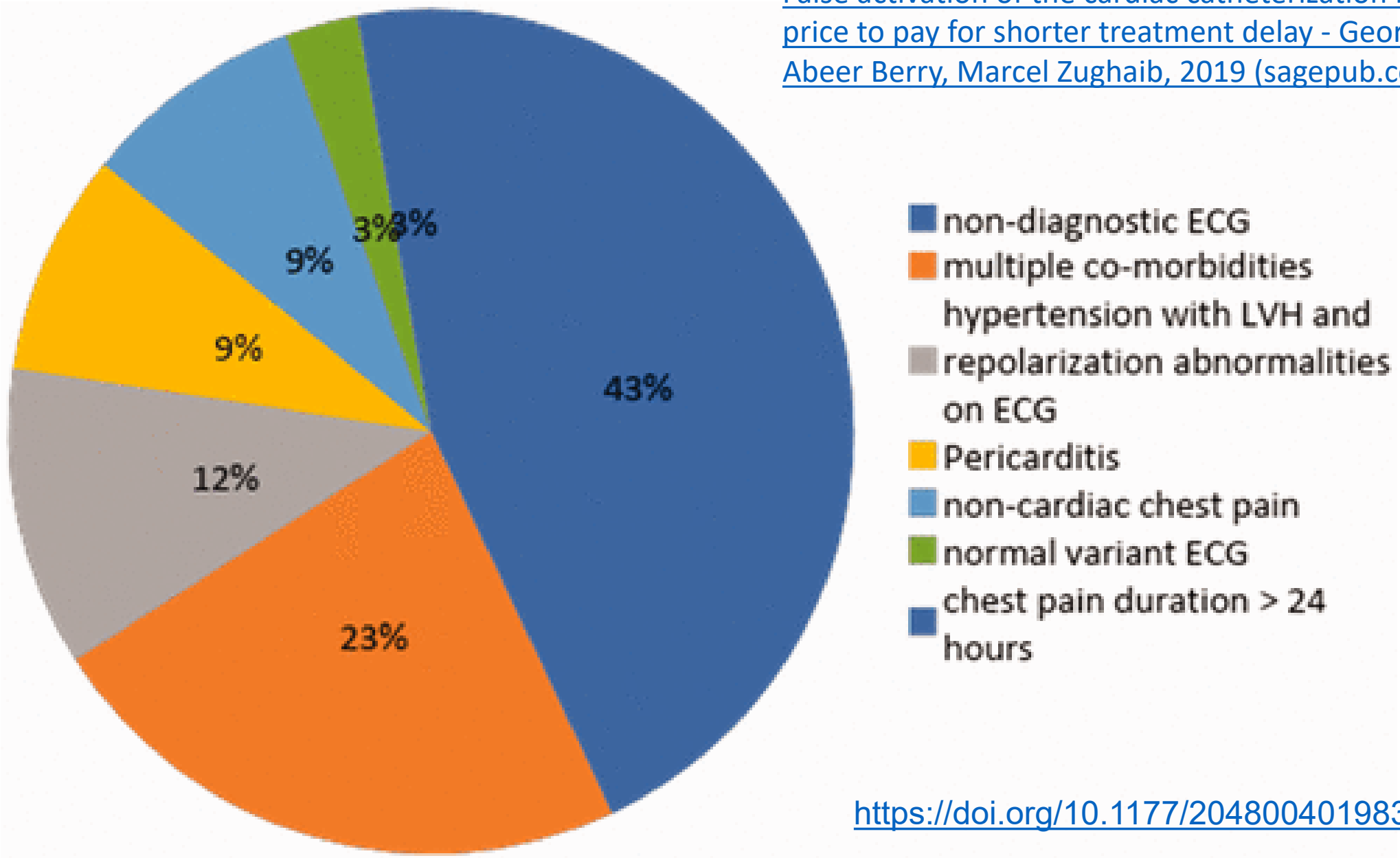
* ECG denotes electrocardiogram, and PCI percutaneous coronary intervention. Adapted from the D2B Alliance.[5]

"The American College of Cardiology (ACC), in collaboration with the American Heart Association (AHA), the American College of Emergency Physicians (ACEP), the National Heart, Lung, and Blood Institute (NHLBI), and other partners, has implemented a national quality-improvement campaign to decrease door-to-balloon time in primary PCI……

…….Matching patients with the most appropriate treatment and location will entail developing a level of coordination and collaboration among hospitals beyond what is currently available in the U.S. health care system but is achievable."

n engl j med 357;16 www.nejm.org october 18, 2007

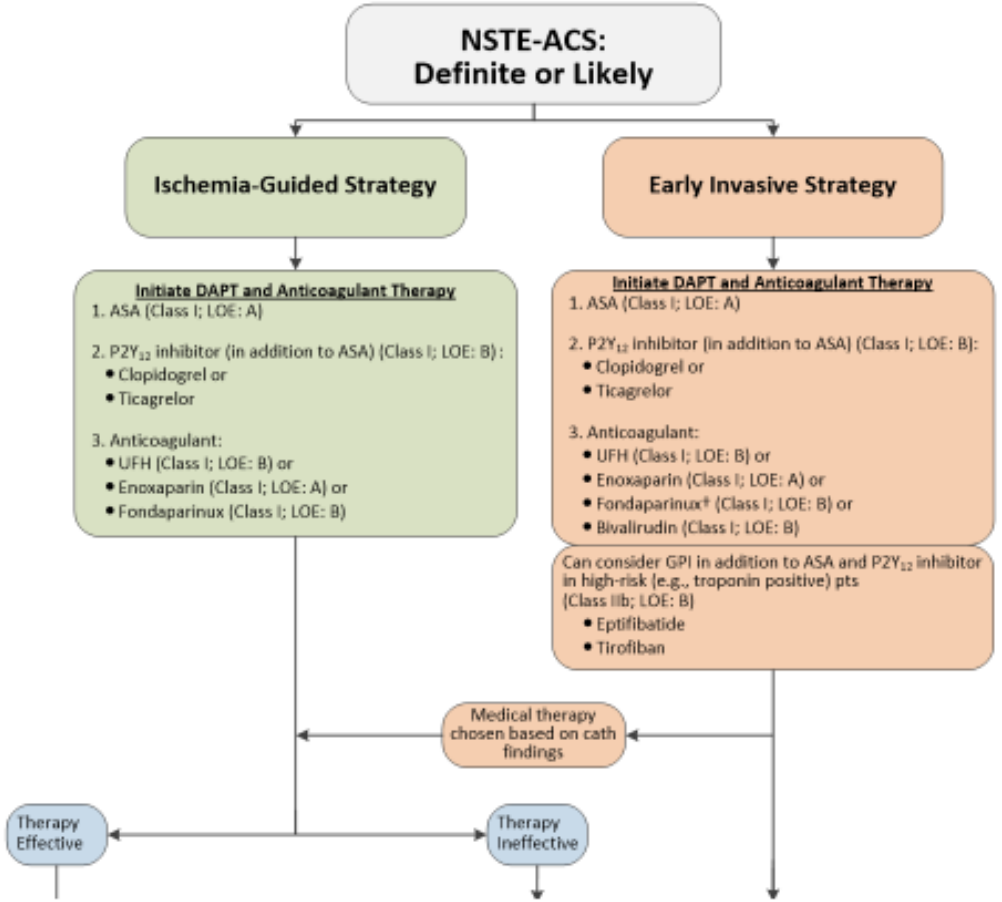
[False activation of the cardiac catheterization laboratory: The price to pay for shorter treatment delay - George Degheim, Abeer Berry, Marcel Zughaib, 2019 (sagepub.com)]

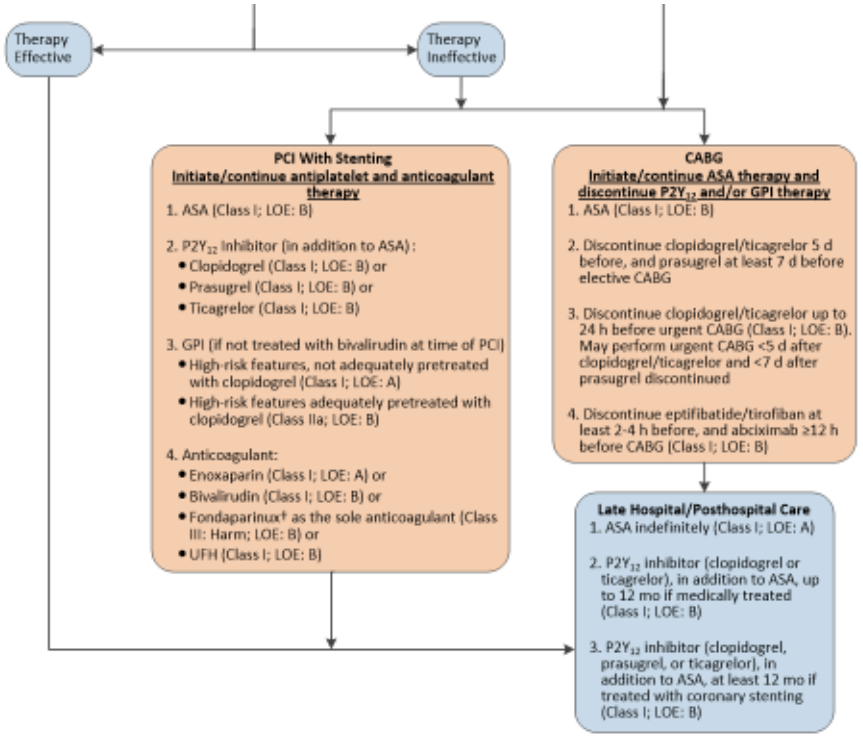


https://doi.org/10.1177/2048004019836365

2014 AHA/ACC Guideline for the Management of Patients With Non–ST-Elevation Acute Coronary Syndromes (NSTE-ACS)

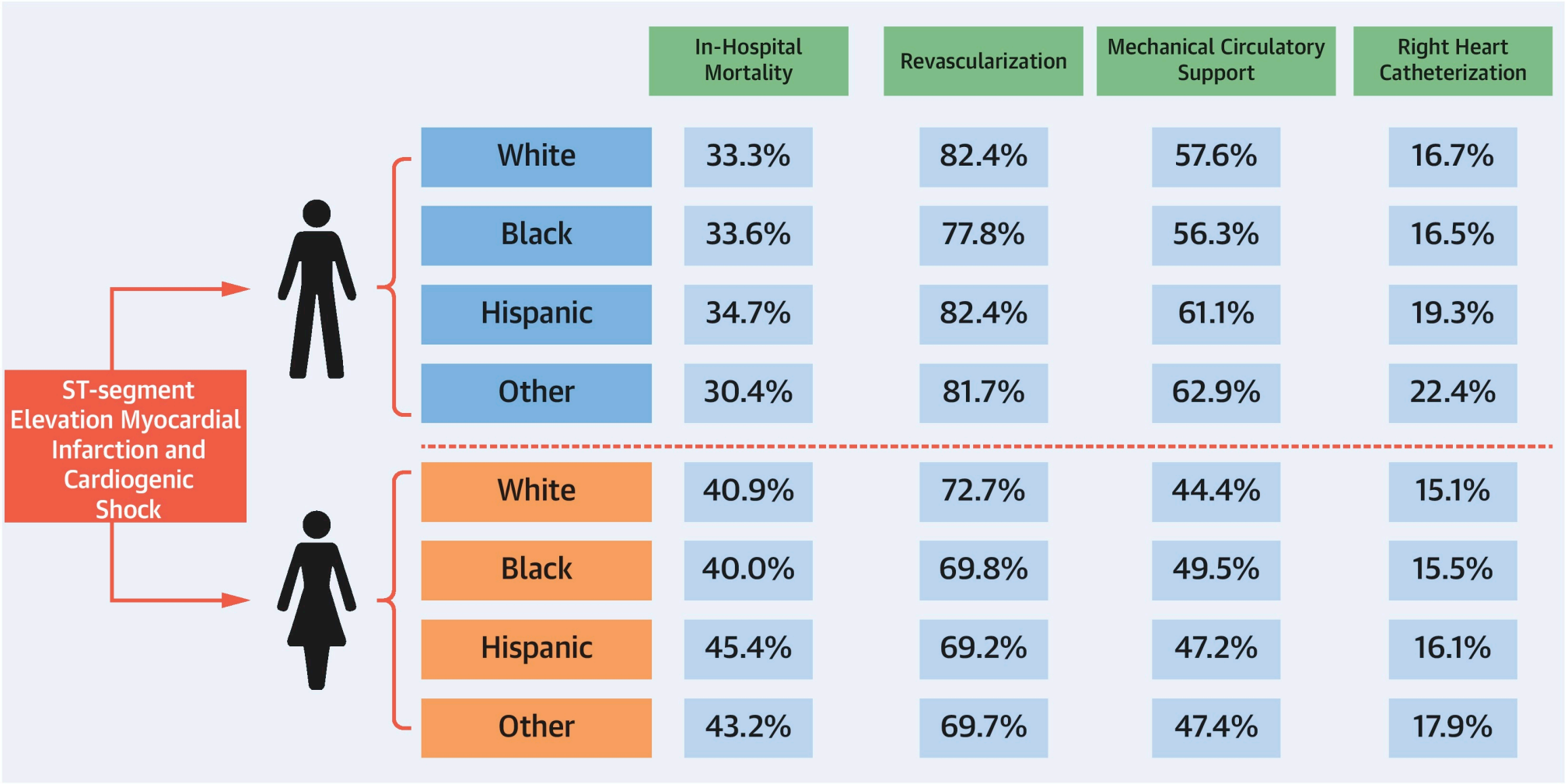
Algorithm for Management of Patients With Definite or Likely NSTE-ACS





†In patients who have been treated with fondaparinux (as upfront therapy) who are undergoing PCI, an additional anticoagulant with anti-IIa activity should be administered at the time of PCI because of the risk of catheter thrombosis.

CENTRAL ILLUSTRATION: Racial, Sex, and Ethnic Disparities in Outcomes of Patients With ST-Segment Elevation Myocardial Infarction and Cardiogenic Shock



	In-Hospital Mortality	Revascularization	Mechanical Circulatory Support	Right Heart Catheterization
White	33.3%	82.4%	57.6%	16.7%
Black	33.6%	77.8%	56.3%	16.5%
Hispanic	34.7%	82.4%	61.1%	19.3%
Other	30.4%	81.7%	62.9%	22.4%
White	40.9%	72.7%	44.4%	15.1%
Black	40.0%	69.8%	49.5%	15.5%
Hispanic	45.4%	69.2%	47.2%	16.1%
Other	43.2%	69.7%	47.4%	17.9%

Ya'qoub, L. et al. J Am Coll Cardiol Intv. 2021;14(6):653-60.

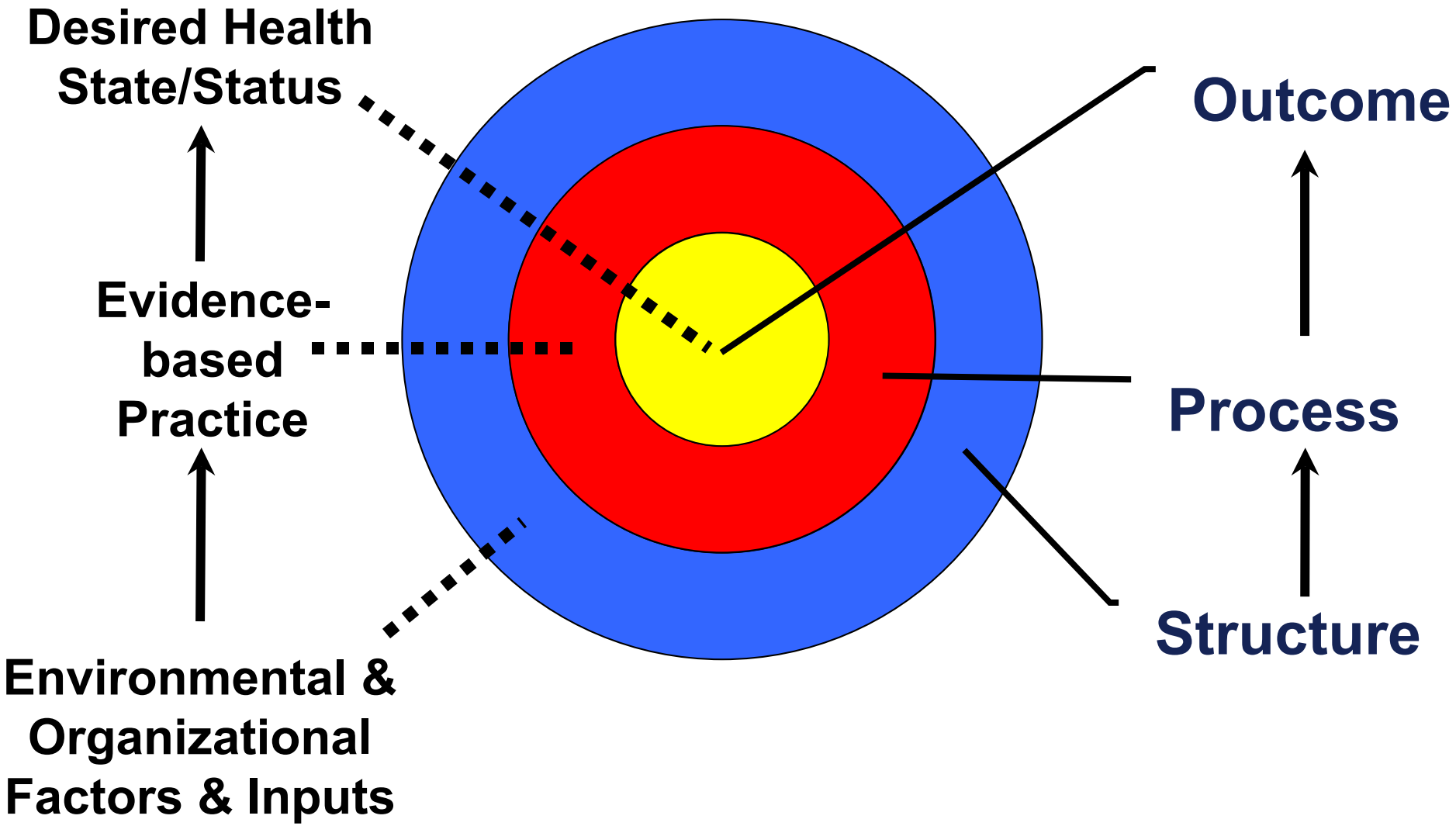
Conclusions

There are significant racial, ethnic, and sex differences in procedural utilization and clinical outcomes in patients with STEMI and CS.

Women are less likely to undergo invasive cardiac procedures, including revascularization and MCS.

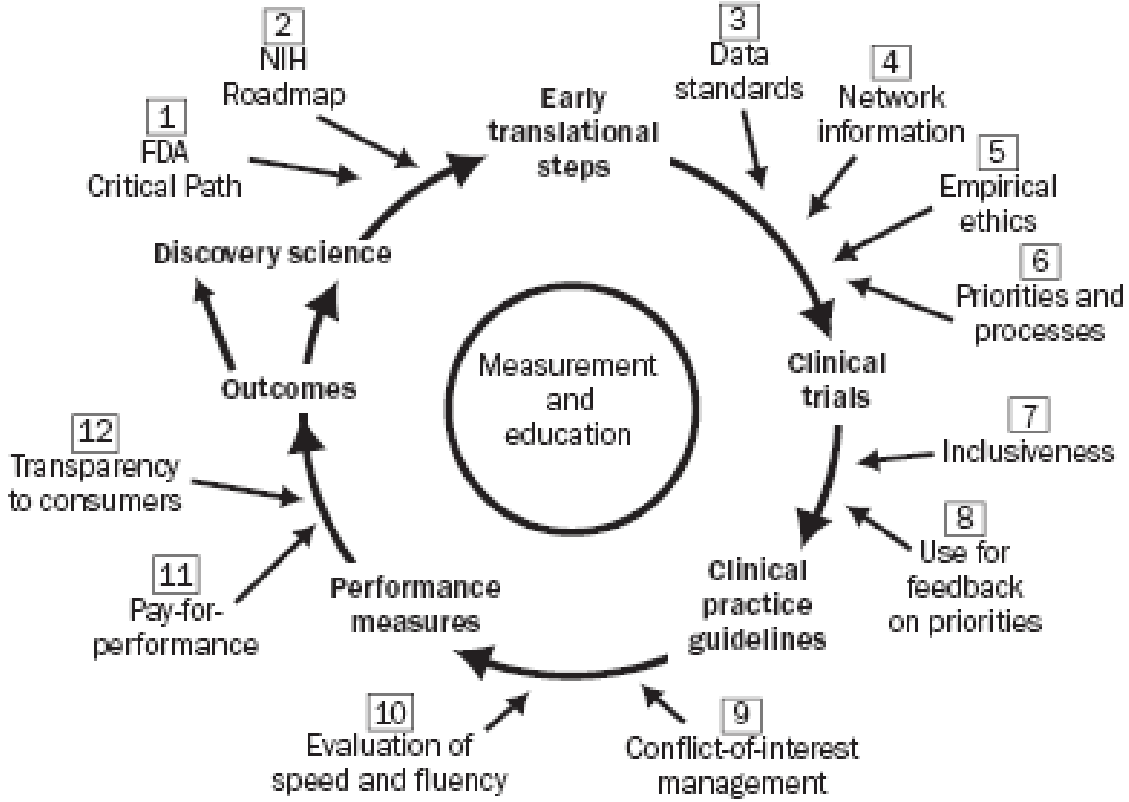
Women as well as Black and Hispanic patients have a higher likelihood of death compared with White men.

Donabedian's Framework for Quality Improvement



[*Health Affairs* 26, no. 1 (2007): 62–74; 10.1377/hlthaff.26.1.62]

EXHIBIT 1
The Cycle Of Quality: Twelve Steps



SOURCE: Adapted with permission from R. Califf et al., "Integrating Quality into the Cycle of Therapeutic Development," *Journal of the American College of Cardiology* 40, no. 11 (2002): 1895–1901.

Applying Classification of Recommendations **(COR)** and Level of Evidence **(LOE)**

Class I	Class IIa	Class IIb	Class III
Benefit >>> Risk Procedure/ Treatment **SHOULD** be performed/ administered	*Benefit >> Risk* *Additional studies with focused objectives needed* **IT IS REASONABLE** to perform procedure/administer treatment	*Benefit ≥ Risk* *Additional studies with broad objectives needed; Additional registry data would be helpful* Procedure/Treatment **MAY BE CONSIDERED**	*Risk ≥ Benefit* *No additional studies needed* Procedure/Treatment should **NOT** be performed/administered **SINCE IT IS NOT HELPFUL AND MAY BE HARMFUL**

Level of Evidence:

Level A:	Data derived from multiple randomized clinical trials or meta-analyses Multiple populations evaluated
Level B:	Data derived from a single randomized trial or nonrandomized studies Limited populations evaluated
Level C:	Only consensus of experts opinion, case studies, or standard of care Very limited populations evaluated

Implementation of Practice Guidelines

Dissemination of guidelines without more intensive behavioral change efforts is not useful to facilitate implementation of practice guidelines.

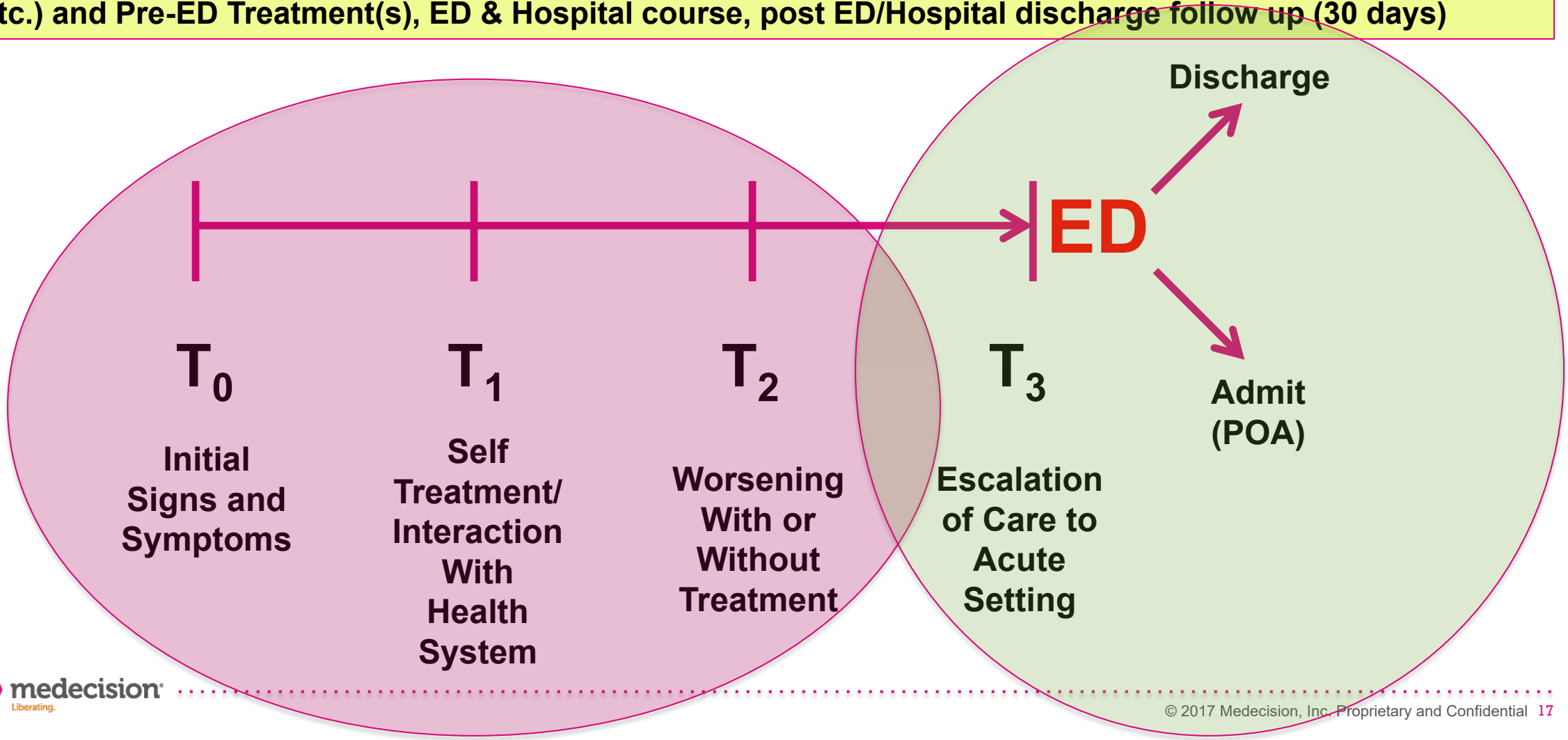
NO CHANGE

Basic provider education alone is not useful to facilitate implementation of practice guidelines.

NO CHANGE

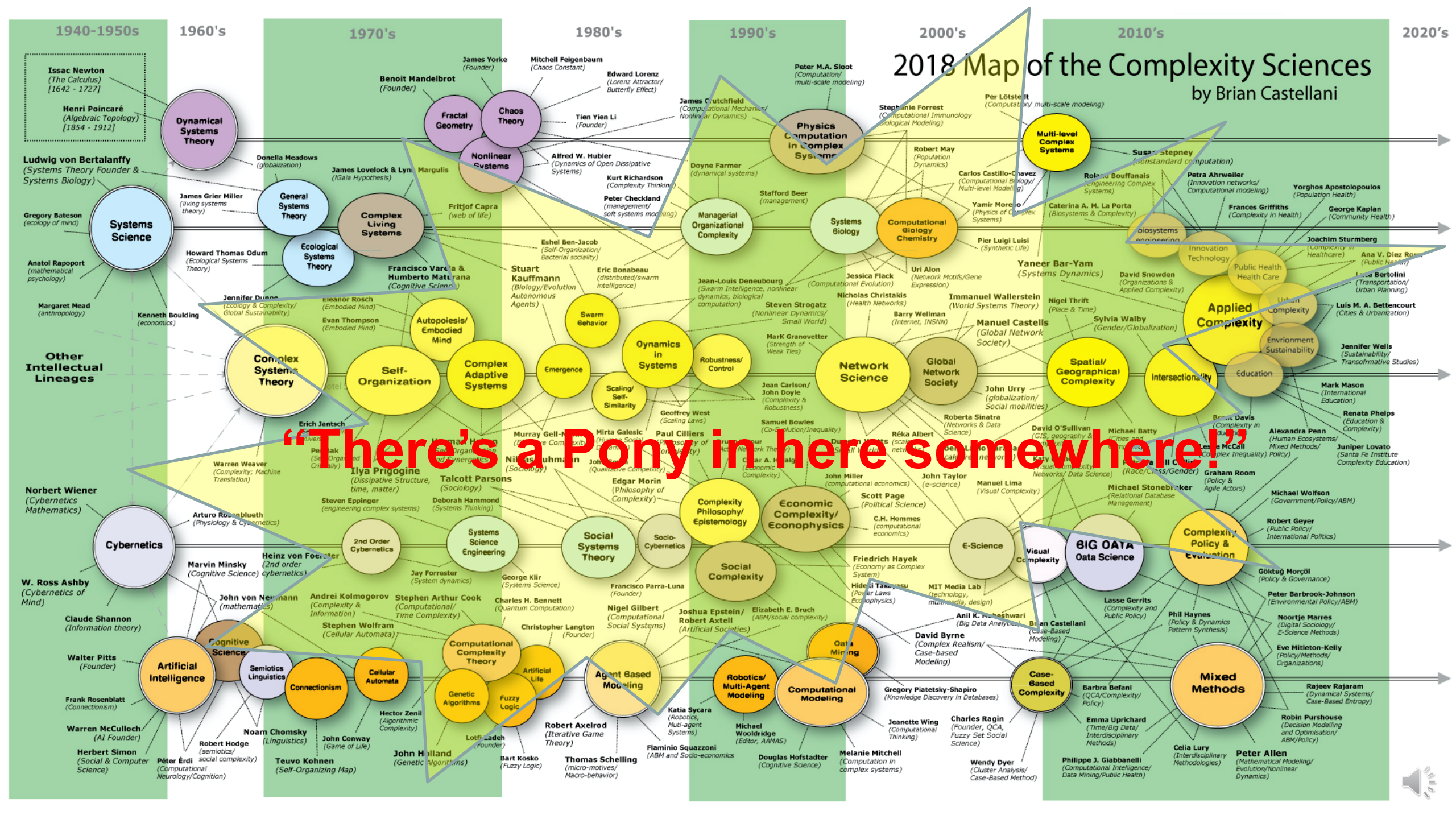
Sepsis Early Warning Assessment Model/Schematic

Stratify Relevant Patient Population by Patient Demographics, Health System Access Points, Comorbidity, Immune Status, Infection Type and Source, Organ System(s), Available Biometrics (e.g. Vital Signs, Labs, etc.) and Pre-ED Treatment(s), ED & Hospital course, post ED/Hospital discharge follow up (30 days)



STEMI/Acute Coronary Syndrome Summary

1. This complex system of care is time dependent and an intricate composite of many “Structure/Process/Outcome” variables.
2. Multiple and sequential diagnostic steps inform the specific subsequent interventions.
3. A better understanding of the details of the evolution of antecedent events occurring before the activation of EMS/ACS Systems of care is necessary, especially patient factors.
4. This understanding may likely inform an “earlier” and more precise and effective Early Warning System of Care for STEMI/ACS.


2018 Map of the Complexity Sciences
by Brian Castellani
1940-1950s
1960's
1970's
1980's
1990's
2000's
2010's
2020's
"There's a Pony in here somewhere!"
Issac Newton (The Calculus) [1642 - 1727]
Henri Poincaré (Algebraic Topology) [1854 - 1912]
Dynamical Systems Theory
Ludwig von Bertalanffy (Systems Theory Founder & Systems Biology)
Systems Science
Gregory Bateson (ecology of mind)
Anatol Rapoport (mathematical psychology)
Margaret Mead (anthropology)
Kenneth Boulding (economics)
Other Intellectual Lineages
Norbert Wiener (Cybernetics Mathematics)
Cybernetics
W. Ross Ashby (Cybernetics of Mind)
Claude Shannon (Information theory)
Warren Weaver (Complexity; Machine Translation)
Arturo Rosenblueth (Physiology & Cybernetics)
Heinz von Foerster (2nd order cybernetics)
Marvin Minsky (Cognitive Science)
John von Neumann (mathematics)
Walter Pitts (Founder)
Frank Rosenblatt (Connectionism)
Warren McCulloch (AI Founder)
Herbert Simon (Social & Computer Science)
Péter Érdi (Computational Neurology/Cognition)
Robert Hodge (semiotics/ social complexity)
Noam Chomsky (Linguistics)
Teuvo Kohnen (Self-Organizing Map)
John Conway (Game of Life)
Hector Zenil (Algorithmic Complexity)
John Holland (Genetic Algorithms)
Lotfi Zadeh (Founder)
Bart Kosko (Fuzzy Logic)
Robert Axelrod (Iterative Game Theory)
Thomas Schelling (micro-motives/ Macro-behavior)
Katia Sycara (Robotics, Muti-agent Systems)
Flaminio Squazzoni (ABM and Socio-economics)
Michael Wooldridge (Editor, AAMAS)
Douglas Hofstadter (Cognitive Science)
Melanie Mitchell (Computation in complex systems)
Jeanette Wing (Computational Thinking)
Gregory Piatetsky-Shapiro (Knowledge Discovery in Databases)
Charles Ragin (Founder, QCA, Fuzzy Set Social Science)
Wendy Dyer (Cluster Analysis/ Case-Based Method)
Barbra Befani (QCA/Complexity/ Policy)
Emma Uprichard (Time/Big Data/ Interdisciplinary Methods)
Philippe J. Giabbanelli (Computational Intelligence/ Data Mining/Public Health)
Celia Lury (Interdisciplinary Methodologies)
Peter Allen (Mathematical Modeling/ Evolution/Nonlinear Dynamics)
Robin Purshouse (Decision Modelling and Optimisation/ ABM/Policy)
Rajeev Rajaram (Dynamical Systems/ Case-Based Entropy)
Eve Mitleton-Kelly (Policy/Methods/ Organizations)
Noortje Marres (Digital Sociology/ E-Science Methods)
Peter Barbrook-Johnson (Environmental Policy/ABM)
Göktuğ Morçöl (Policy & Governance)
Robert Geyer (Public Policy/ International Politics)
Michael Wolfson (Government/Policy/ABM)
Graham Room (Policy & Agile Actors)
Juniper Lovato (Santa Fe Institute Complexity Education)
Alexandra Penn (Human Ecosystems/ Mixed Methods/ Policy)
Mark Mason (International Education)
Renata Phelps (Education & Complexity)
Jennifer Wells (Sustainability/ Transofrmative Studies)
Luis M. A. Bettencourt (Cities & Urbanization)
Luca Bertolini (Transportation/ Urban Planning)
Joachim Sturmberg (Complexity in Healthcare)
Ana V. Diez Roux (Public Health)
Yorghos Apostolopoulos (Population Health)
Frances Griffiths (Complexity in Health)
George Kaplan (Community Health)
Petra Ahrweiler (Innovation networks/ Computational modeling)
Susan Stepney (Unconstandard computation)
Per Lötstedt (Computation/ multi-scale modeling)
Peter M.A. Sloot (Computation/ multi-scale modeling)
James Crutchfield (Computational Mechanics/ Nonlinear Dynamics)
Stephanie Forrest (Computational Immunology Biological Modeling)
Robert May (Population Dynamics)
Carlos Castillo-Chavez (Computational Biology/ Multi-level Modeling)
Yamir Moreno (Physics of Complex Systems)
Pier Luigi Luisi (Synthetic Life)
Caterina A. M. La Porta (Biosystems & Complexity)
Roberto Bouffanais (Engineering Complex Systems)
Yaneer Bar-Yam (Systems Dynamics)
David Snowden (Organizations & Applied Complexity)
Nigel Thrift (Place & Time)
Sylvia Walby (Gender/Globalization)
John Urry (globalization/ Social mobilities)
Michael Batty (Cities and Complexity)
Michael Stonebraker (Relational Database Management)
Lasse Gerrits (Complexity and Public Policy)
Phil Haynes (Policy & Dynamics Pattern Synthesis)
Brian Castellani (Case-Based Modeling)
David Byrne (Complex Realism/ Case-based Modeling)
Anil K. Maheshwari (Big Data Analytics)
Friedrich Hayek (Economy as Complex System)
MIT Media Lab (technology, multimedia, design)
John Taylor (e-science)
Manuel Lima (Visual Complexity)
Scott Page (Political Science)
C.H. Hommes (computational economics)
John Miller (computational economics)
Roberta Sinatra (Networks & Data Science)
Samuel Bowles (Co-evolution/Inequality)
Jean Carlson/ John Doyle (Complexity & Robustness)
Geoffrey West (Scaling Laws)
Mirta Galesic (Human Social Cognition)
Paul Cilliers (Philosophy of Complexity)
Edgar Morin (Philosophy of Complexity)
Ilya Prigogine (Dissipative Structure, time, matter)
Talcott Parsons (Sociology)
Deborah Hammond (Systems Thinking)
Steven Eppinger (engineering complex systems)
Jay Forrester (System dynamics)
George Klir (Systems Science)
Francisco Parra-Luna (Founder)
Nigel Gilbert (Computational Social Systems)
Joshua Epstein / Robert Axtell (Artificial Societies)
Elizabeth E. Bruch (ABM/social complexity)
Christopher Langton (Founder)
Andrei Kolmogorov (Complexity & Information)
Stephen Arthur Cook (Computational/ Time Complexity)
Charles H. Bennett (Quantum Computation)
Stephen Wolfram (Cellular Automata)
Eshel Ben-Jacob (Self-Organization/ Bacterial sociality)
Stuart Kauffmann (Biology/Evolution Autonomous Agents)
Eric Bonabeau (distributed/swarm intelligence)
Jean-Louis Deneubourg (Swarm Intelligence, nonlinear dynamics, biological computation)
Jessica Flack (Computational Evolution)
Uri Alon (Network Motifs/Gene Expression)
Nicholas Christakis (Health Networks)
Steven Strogatz (Nonlinear Dynamics/ Small World)
Barry Wellman (Internet, INSNN)
MarK Granovetter (Strength of Weak Ties)
Immanuel Wallerstein (World Systems Theory)
Manuel Castells (Global Network Society)
Howard Thomas Odum (Ecological Systems Theory)
Jennifer Dunne (Ecology & Complexity/ Global Sustainability)
Eleanor Rosch (Embodied Mind)
Evan Thompson (Embodied Mind)
Francisco Varela & Humberto Maturana (Cognitive Science)
Erich Jantsch
Peter Cloak (Self-Organized Criticality)
Nils Luhmann (Sociology)
Murray Gell-Mann (Plectics/ Complexity)
Mirta Galesic (Human Social Cognition)
John Holland (Qualitative Complexity)
Réka Albert (scale-free networks)
Cesar A. Hidalgo (Economic Complexity)
Duncan Watts (Small World Networks)
Albert-László Barabási (Network Science)
Fritjof Capra (web of life)
James Lovelock & Lynn Margulis (Gaia Hypothesis)
James Grier Miller (living systems theory)
Donella Meadows (globalization)
General Systems Theory
Ecological Systems Theory
Complex Living Systems
Nonlinear Systems
Fractal Geometry
Chaos Theory
Benoit Mandelbrot (Founder)
James Yorke (Founder)
Mitchell Feigenbaum (Chaos Constant)
Edward Lorenz (Lorenz Attractor/ Butterfly Effect)
Tien Yien Li (Founder)
Alfred W. Hubler (Dynamics of Open Dissipative Systems)
Kurt Richardson (Complexity Thinking)
Peter Checkland (management/ soft systems modeling)
Doyne Farmer (dynamical systems)
Stafford Beer (management)
Managerial Organizational Complexity
Physics Computation in Complex Systems
Systems Biology
Computational Biology Chemistry
Multi-level Complex Systems
Applied Complexity
Innovation Technology
Public Health Health Care
Urban Complexity
Envrionment Sustainability
Education
Spatial/ Geographical Complexity
Intersectionality
Network Science
Global Network Society
Complex Systems Theory
Self-Organization
Complex Adaptive Systems
Autopoiesis/ Embodied Mind
Emergence
Swarm Behavior
Oynamics in Systems
Robustness/ Control
Scaling/ Self-Similarity
Complexity Philosophy/ Epistemology
Economic Complexity/ Econophysics
Social Systems Theory
Socio-Cybernetics
Social Complexity
2nd Order Cybernetics
Systems Science Engineering
E-Science
Visual Complexity
BIG DATA Oata Science
Complexity Policy & Evaluation
Cognitive Science
Artificial Intelligence
Semiotics Linguistics
Connectionism
Cellular Automata
Computational Complexity Theory
Genetic Algorithms
Fuzzy Logic
Artificial Life
Agent Based Modeling
Robotics/ Multi-Agent Modeling
Computational Modeling
Oata Mining
Case-Based Complexity
Mixed Methods