Practicing Cardiology of the 21st Century

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Introduction

Practicing medicine is a time old tradition. The clinical approach of investigating and treating disease is well documented, tested, and practiced. How can a physician provide better cardiac care with the help of modern information technology (IT)?

In this chapter, the first section is reserved for the usual merits of a clinical approach so dear to the heart of all physicians and health care providers. The second section will discuss the useful application of artificial intelligence (AI) in medicine in general. Different new terms and definitions are clarified for the medical and professional readers. In the third section, how to apply the principles of works and the methodologies of AI in the investigation and management of cardiovascular (CV) disease are discussed. Their clinical applications for 2 CV conditions, the simple coarctation of the aorta (CoA) and the complex acute myocardial infarction (AMI) complicated by heart failure (HF), are presented in detail. In the last section, pro and con of the new approach and principles of how to apply it in the daily practice are suggested.

CONVENTIONAL CLINICAL APPROACH

Diagnostic imaging has made enormous advances in the past 20 years, and has significantly improved the accuracy with which a diagnosis of cardiac disease can be assured. At the same time, the availability of non-invasive imaging has reduced the need for a detailed physical examination that was the hallmark and pride of clinical cardiology. This section will discuss the continuing need for an accurate and thorough history, physical examination (H and P), and comprehensive management plan in the evaluation and management of patients with known or suspected cardiac disease. All of these are done through the lens of (1) a physician or (2) a Computer Automated Decision Support System (DSS) or (3) a physician equipped with an Automated DSS.

Investigative Plan In all patient encounters, it is essential to understand the reason for the patient's need for a cardiac consultation. Failing to understand the chief complaint will impair the physician's ability to focus on solutions to both the diagnosis and therapy. At the same time, the physicians should approach the patient with an open mind, without prejudice or using racial, age, or gender profiling.

Within the first 5 minutes of a conventional history interview, the large area of investigation of a cardiac symptom or disease should be narrowed gradually to a few major leads. The method used is a deductive analysis based on the initial symptoms, with the "if…then" process-- a core programming construct, widely used in information technology (IT) language, and now being re-applied in the medical diagnostic investigation. (1) The questions from a broad spectrum are narrowing down to be more specific in time, place, location, and characteristic. The goal is to try to establish a plan to lead the investigative trail for a subsequent comprehensive H and P to support diagnoses considered in the differential diagnosis. So the guiding plan is flexible and modifiable according to the details which keep emerging from the on-going history interview and physical examination. The diagnosis to be identified and the differential diagnoses to be ruled out are moving targets.

Other Information In all patients for whom a diagnosis can or cannot be made based on the initial history, a complete review of systems is still indicated in order to uncover any additional potential information. The social and family history should be asked in detail. Patients' medications should be reviewed. Recent changes in medications should be addressed to rule out drug-to-drug interactions or a new side effect. Allergy information should be gathered and the specifics of the reaction should be documented.

Preliminary diagnosis and differential diagnoses Once the H and P is done, the physician would look at all sources of data for decision-making including the results of previous studies, hospital records, physician's notes, and information from family members. From there, the physician can deduct a preliminary working diagnosis and a short list of differential diagnoses. For a physician specializing in cardiovascular disease, it is vital to not misdiagnose or miss some major and important diagnoses. (Table 1.1)

Table 1.1 Diagnoses that Physicians Should not Miss

1. Acute myocardial infarction
2. Acute surgical abdomen
3. Dissection of aortic aneurysm
4. Cardiac tamponade

5. Pulmonary embolism
6. Transient ischemic attack and stroke
7. Acute mitral regurgitation
8. Acute aortic regurgitation
9. Subacute bacterial endocarditis

Selection of the Right Tests With the preliminary working diagnosis and a short list of differential diagnoses, it is necessary to confirm the diagnosis and rule out the differential diagnoses by objective tests. To make a diagnosis is to evaluate a test and then to use it in order to estimate the probability that a patient has a given disease. The results of the test also help to determine whether one therapy or another would be a better choice. The selection of a test depends on several factors, including availability of technology, local experience on a given modality, patient-specific factors, and pretest and post-test probability within a context of time and cost-effective approach. (Table 1.2)

Table 1.2 Concerns before ordering tests

1. Pre-test probability
2. Sensitivity and specificity
3. What is the least risky strategy for the patient?
   False negative diagnosis
   False positive diagnosis
4. Are there guidelines for appropriate use of tests?
5. Should cost be considered in the evaluation?
6. Are you chasing a red herring?
7. Are they urgent or emergency situations?
8. Is the availability of facilities limited?

Should all the tests be done selectively or is there a place for the "do everything at once" shotgun approach? How to do cost- and time-effective testing on an individual and societal basis? A continued provision of excellent cost-effective care is due to reduced overuse of imaging and procedures. However, the diagnostic accuracy of the tests has to be confirmed first before their cost-effectiveness can be estimated.

Art or Science Clinical diagnosis is an art that depends on creating likelihoods for a list of diagnoses. It is also a science based on long years of learning and experience. What else can help the physicians to provide better care for cardiovascular disease patients? (1)

ARTIFICAL INTELLIGENCE TECHNOLOGY

Scientists and physicians have been "manually" extracting information from data for centuries, but the overwhelming volume of data after the explosion of the Internet requires more automatic approaches. As data sets and the information extracted from them have grown dramatically in size and complexity, direct hands-on data analysis has become obsolete. (2)

With the proliferation, ubiquity, and increasing power of computer technology aiding data collection, processing, management and storage, the captured data need to be converted into information and once the information is verified, it becomes clinically useful knowledge. Even so, medical knowledge has become so vast and complicated that no one human brain can memorize everything. Computers are designed exactly for that -- to sift through huge databases and match known questions and answers. It is crucial to know what kind of data, what types of tools, functions, and methods can help the physicians in culling these to arrive at only essential information. (2) The ultimate goal is to provide a faster solution to patient problems, improve delivery of care, and reduce errors during treatment.

Clinical Investigation (Data collecting) The physicians can gather the clinical information about the patient by asking questions during the history interview and examining the patient during the physical exam. The data collected by a physician should be arranged in a structured, systematic, and scientific fashion so subsequent clinical decisions based on arguments embodied in the findings are valid. (3) The process of doing an H and P is called "**Data Collecting**".

Clinical Pearls (Data Decoding Tips) When the meaning of symptoms and signs are not understood and need to be explained in order to become applicable information, then the process of deciphering the symptoms and signs is called **"Data Decoding".**

Preliminary Diagnosis (Data Processing) Data analysis is a process of gathering, modeling, and transforming data with the goal of highlighting useful information, suggesting conclusions, and supporting decision making. (4) The first step is called "**Data Processing"** which may be simple or complex, depending on context. Simple problems may be identified and resolved with few iterations of data collecting and data processing.

Complex problems may require many iterations of data collection from various sources (i.e. results of tests), and interfacing with Decision Support systems that support diagnosis of complex problems. If the process is complex, requiring input of a physician to arrive at a clinical diagnosis, it is called "**Data Converting**".

After formulating a preliminary working diagnosis and a short list of differential diagnoses, in the next step, the physician will order the least number of tests to confirm the working diagnosis and to rule out the differential diagnoses.

Extraclinical Investigation by Testing (Data Mining) According to traditional teaching, the clinical investigation is the bedside H and P. When the patient undergoes testing, it is called extra-clinical or paraclinical investigation. This terminology creates an impression that extra-clinical investigation is the testing done outside the clinical spectrum, inside the confinement of a laboratory or literally, "outside the patient's body". This is in contrast to the new concept of "**Data Mining**".

Definition In information technology (IT) terminology, the term "Data Mining" means to extract data from and to look for patterns in a database. The resulting patterns may lead to either asking new questions, or finding answers to solve a problem. Applying it to medicine, data mining is sending a command to look for data inside the database which is the body of the patient. This concept is important because from the view of an Automated DSS or of a physician, all the clinical questions and answers are inside the body of a patient, sitting, lying, or standing in front of the examining physician. The only thing that she or he has to do is to go inside the patients, look for the right data, and extract the right results to solve the medical problems. With this new understanding, the term data mining opens to a really new, meaningful perspective.

This new concept is important because the physicians now know exactly where the answer is. However, the 1 million dollar question is: How does one get the data from inside the patient in a human and cost-effective way?

Technique Data mining involves using analysis techniques that focuses on modeling and knowledge discovery for descriptive purposes. The processes of data mining may range from the transparent (e.g., rule-based approaches) through to the opaque (e.g., "neural networks") through "Classification," "Clustering Regression," "Association rule learning" by using programs or algorithms such as "Nearest neighbor," "Naive Bayes classifier," or "Genetic Programming". Data mining leads to "Predictive Analytics", where collected information may be analyzed for prognostic outlook. (5)

Differential diagnosis (Data Filtering) "**Data Filtering**" is ruling out the possibility of other relevant diagnoses. The process is by discrimination, or parsing between relevant and irrelevant data.

Main diagnosis (Data Converting) "Data Converting" is using the information to make a definitive diagnosis. This is the main role reserved for a physician. No computers, lay persons, nor other health care providers are able to perform this important job because it is the result of a complex process of reasoning and rationalizing. This action of data converting (making a diagnosis) also imposes on the physician a moral and legal responsibility for his or her clinical decision. A computer program does not bear any legal or moral responsibility. If a physician does not do this data converting job well or his or her performance is substandard (e.g. making too many wrong diagnoses), then this particular physician does not yet fulfill his or her duty assigned by the society.

CARDIAC INVESTIGATION and MANAGEMENT in the 21st CENTURY

When a physician comes to see a patient, there is a need to define the main question or problem to be solved. The main problem can be a symptom, a sign, or a disease condition and the goal can be an investigation or disease management.

In this first decade of the 21st century, how can a physician evaluate and manage patients with the time honored medical tradition combined with the assistance of a computer? The goal is not for a middle-aged cardiologist to behave like a today's teenager with an iPhone, iPod, Facebook or to be connected to the Internet 24/7. These accessories do not bring a cardiologist to the 21st century.

In a hospital or in society, the goal of the new way of working with AI is to improve the quality, safety, and efficiency of medical care by maximizing the use of clinical information technology in key issues such as complex clinical workflows, usability, controlled terminology, knowledge management, and clinical decision support.

However, on a personal setting, in a face-to-face encounter between a physician and a patient, the new methodology assisted by AI is the new way how to scrutinize, dissect, and solve a medical problem (from diagnosis to treatment and prevention) through maximizing the management of knowledge and information technology resources. It is through the use of the AI methodologies (and not just the commercial application of AI) which are the key success factors for the improvement of efficacy and efficiency in delivering quality cardiac care.

Areas in Focus Based on a Computational Model At the bedside, while asking questions in the history taking and performing a complete physical examination, how can a physician know that he or she has exhausted all the questions about (subjective) symptoms, and all the searches for (objective) signs? Has he or she ordered the least number of needed tests? Has she or he delivered all the best indicated treatments? One of the answers is that the patient is to be checked from head to toe or that all the systems are to be searched on an anatomical basis. The other way is to use an AI program for data collecting (symptoms and signs) and data mining (laboratory, non-invasive and invasive tests). Which are the different areas to be focused on by an AI program for data collecting and data mining? They are listed in table 1.3.

Table **1.3 Areas in Focus Based on a Computational Model**

1. **The area of interest or index problem**
2. **The area proximal to or upstream to** the index problem with hyperdynamic producing activities (compensatory state) or overwhelmed compensatory condition (disease state)
3. **The area distal or downstream to** the index problem with hyperdynamic receiving capacity (compensatory state) or overwhelmed compensatory condition (disease state)
4. **The configuration** of the system or network
5. **The work-around configuration** (the bypass system)
6. **The system** (the cardiovascular system)
7. **The network** (the whole body is a network of systems)

In each of these areas, the clinical aspects to be documented include the derangement caused by the index section, failure of the distal segment, compensation of the proximal and distal section, work-around configuration as a temporary solution and adaptation to function at lower capacity of the cardiovascular system. Once all data are collected, classified, and integrated, and a diagnosis is pronounced, the physician would suggest a standard treatment plan based on current guidelines with the assistance of AI. The treatment is to determine whether a treatment is beneficial in patients with a given disease, and if so, whether the benefits outweigh the costs and risks. The advanced management consists of a treatment plan tailored to the patient's own characteristics and its gradual modification following the success of or failure to each step of the standard treatment.

A Computational Cardiac Model From an IT perspective, the heart is designed and functions like a sophisticated computer system, incorporated inside a complex super-network (which is the body). The anatomical structure of the heart is the hardware. The mechanism running the heart's contractile function is the software. The smooth relation between the heart and other organs such as the lungs, the kidneys, or the interactions between different chambers of the heart are the results of an elaborate configuration and intricate mechanism.

For example, mitral stenosis is a hardware problem, obstructing the blood flow at the level of the mitral valve. Essential hypertension (HTN) is caused by a software problem, because the blood pressure is set abnormally high without any anatomical abnormality. It is similar to a house in summer with the heating machine in full speed because the thermostat is set high, while the air conditioning will cool the house nicely if turned on. If the HTN is secondary to stenosis of the renal artery, then this is a hardware problem. In patients experiencing uncontrolled supraventricular tachycardia and wide QRS complex due to Wolf-Parkinson-White syndrome, the problem is clearly a configuration problem because of the aberrant connections between the atrium and ventricle through abnormal electrical lines.

Interactions and Coupling in a Computational Model In general, there are 2 kinds of relations between components of a system: interaction and coupling. Interactions refer to the linear or complex dependencies between components, while coupling refers to the loose or tight flexibility in a system. The systems with simple, linear interactions have components that affect only other components that are functionally downstream. One example is that of a significant lesion in the superficial femoral artery (SFA) which only affects the flow, the nutritional status, and the function of the ipsilateral lower leg downstream.

In contrast, complex system components interact with many other components in different parts of the system. Loosely coupled systems have more flexibility in time constraints, operation sequencing, and assumptions about the environment than do tightly coupled systems. Systems with complex interactions and tight coupling are likely to promote accidents. Complex interactions allow for more complications to develop and make the system hard to understand and predict. Tight coupling also means that the system has less flexibility in recovering when things go wrong. According to these definitions, the cardiovascular system has complex interaction within its components and tight coupling with the pulmonary and renal systems. (6)

To illustrate this new perspective, 3 examples of system disruption and its corrective mechanism and actions are selected and presented. The first example is a hypothetical Internet application. What happens if there is a failure in its infrastructure?

The second example is a patient with coarctation of the aorta. What happens to the patient and how does the body react to it? How does a physician of the 21st century investigate the problem? The third example is the case of a patient with acute myocardial infarction (AMI) complicated by heart failure. How are these problems investigated and treated from the perspective of a physician helped by the AI of an Automated DSS ? Many of the AI technologies in current decision support systems don't need the complexity of a high cost supercomputer. Many can be run on commodity systems that are affordable in comparison.

Corrective Mechanisms in case of an Interruption of a Hypothetical Large Internet Application Infrastructure In this example, there is infrastructure failure of an Internet application provider. Typically such applications are constructed with a redundant and loosely coupled architecture. Failure of the server and network components are not single points of failure. Such components are arranged in *farms* or *clusters*, where the load is more or less evenly distributed. If a single server fails, other servers in the farm or cluster will carry the load by using its reserve capacity until it becomes overloaded. When an overload occurs, the calls in progress do not fail, but they prevent the server from accepting additional calls. Because of the malfunction in the index server, all the activities downstream to it are idle or function at lower capacity, and run at slower speed or shut off (crash or outage).

In the current set-up, the servers in a farm or cluster have little to no dependencies on the other servers in the same farm/cluster. That implies *loose coupling,* which allow for expected failures with little to no disruption to end-users.

In the event of major disruptions to network infrastructure or entire server farms that do result in outage (or crash), typically there are thorough procedures in place to rapidly "work around" known types of problems, and/or stabilize the system to render it usable until the problem's root cause can be diagnosed and corrected.

Corrective Mechanisms in Case of an Interruption of the Cardiovascular System on a Computational Cardiac Model Applying the same corrective mechanisms of an IT structure to a computational cardiac model, in the case of CoA, the index lesion is the narrowing area in the isthmus of the thoracic descending aorta. There is dilation (hyperdynamic compensatory activity) of the segment proximal to the index lesion. The segment distal to the index lesion is hypoplastic. Collaterals from the upper body through the internal mammary and the intercostal arteries channel blood to the lower body by the work-around set-up (collaterals). Because of CoA, there is high blood pressure and over-development of the upper body while there is low blood pressure and underdevelopment of the lower half of the body. The patient would complain of headache because of high BP and claudication due to insufficient blood below the isthmic narrowing. The lower extremities are cold and the distal pulses are weak. If there are enough collaterals and augmentation from the reflecting wave, then the distal pulses at the ankles can be felt normally. According to the computational cardiac map, the CoA functions with linear interactions and loose coupling. The summaries of data collecting, mining and treatment for CoA based on a computational cardiac model are listed in table 1.4.

Table 1.4 Data Collecting, Mining and Treatment for CoArctation of the Aorta on a Computational Cardiac Model

CoArctation of the Aorta	**Main Area of interest**	**Proximal to index problem**	**Distal to index problem**	**Work-around configuration**
Location	**Narrowing** at isthmus	Prestenotic **dilation, HTN**	Post-stenotic **low flow**	**Collaterals**
Symptoms	None	**Headache**	**Claudication**	None
Signs	Pathognomonic sign: none	**HTN** in well developed upper body,	**Weak pulse, atrophy** in lower body	**collaterals, murmur** in back
Direct tests	**Aortogram** **CT** of chest	**Aortogram** **CT** of chest	**Aortogram** **CT** of chest	
Indirect tests	None	CXR with the reverse 3 image	CXR with the reverse 3 image	CXR with **notched rib**
Target treatment	**Stent or end to end surgery**	**Control HTN**	None	None
Work-around	**Bypass graft**	None	None	None

Assessment and Management of a Patient with Myocardial Infarction and Heart Failure based on a Computational Cardiac Model The heart is a major component in the complex cardiovascular system. It has intricate interaction and tight coupling between its own chambers and with other adjacent organs. The functions of the heart governed by different mechanisms include:

1. The myocardium contracts under the principles of physics.
2. The atria and ventricles circulate the blood under the principles of hydraulics.
3. The electrical system triggers and stimulates the atrial and ventricular contractions
4. The coronary arteries supply the blood to the myocardium

All the four components above function under tight control and coordination of the nervous and hormonal regulatory systems. In the following 4 sections, the process of soliciting symptoms and signs, testing and treatment based on the 7 areas of focus from the computational cardiac model is discussed in details.

Data Collecting (History interview) Applying the same corrective mechanisms on a computational cardiac model to a patient with AMI complicated by heart failure, the main area in focus is the index lesion with acute occlusion of the infarct-related artery (IRA). There is prestenotic dilation (hyperdynamic compensatory activity) of the coronary artery segment proximal to the index lesion. The coronary segment distal to the index lesion could be dilated (positive remodeling) or constricted due to low flow. There are collaterals from the proximal coronary segment to the distal vasculature (work-around set-up). There are no symptoms and signs related to the segment proximal to the index lesion. The patient experiences chest pain because of acute and prolonged occlusion of the index lesion causing ischemia in the myocardium supplied by the coronary artery segment distal to the index lesion. The pain does not come from the index lesion of the IRA. There are no symptoms from the work-around configuration. The mechanism and origin of chest pain in AMI is illustrated in table 1.5.

Table 1.5 Mechanism and Origin of Chest Pain in AMI

	Index lesion	**Proximal coronary segment**	**Distal coronary segment**	**Myocardium downstream of the index lesion**
Mechanism	Occlusion at the lesion	Compensatory dilation	Constriction due to slow flow	Ischemia due to lack of blood
Symptom generated	None	None	None	**Chest pain**

If the myocardium supplied by the index artery is large, there would be wall motion abnormality with left ventricular dysfunction, lower cardiac output and mainly lower blood pressure. The response from the upstream section of the left ventricle is to increase the sympathetic drive causing increased heart rate and blood pressure (BP) which hopefully delivers (1) the amount of blood required for the body metabolism and (2) better perfuses the distal segment of the IRA. Because of the increased sympathetic output, the patient could feel apprehensive and complain of palpitation (even though the heart rate is not very high yet).

In contrast, at the distal extremities, due to low BP, the patient could feel cold because of vasoconstriction. If the BP is low enough, the effect of low BP will be evidenced in the cerebral system as the patient complains of dizziness, lightheadedness, and syncope. If there is severe LV dysfunction, then there are symptoms of shortness of breath due to lung congestion (upstream to the LV). There are no signs from the work-around configuration. The mechanisms and origins of these symptoms are illustrated in table 1.6.

Table 1.6. Mechanism and Origin of Symptoms due to LV Dysfunction

	Index area	**Upstream to the index area**	**Downstream to the index area (system)**	**Downstream to the index area (network)**
	Left ventricle	Pulmonary vasculature	Aorta and distal vasculature	Cerebral vasculature
Mechanism of disease	Left ventricular failure	Fluid overload	Decrease blood pressure	Decrease blood pressure
Symptoms generated	Sense of **palpitation** due to increased heart rate	**Feeling cold** in feet	**Shortness of breath**	**Lightneadness, dizziness, confusion**

Data Collecting (Physical examination) In the physical examination, there are no objective signs pointing exactly to the acute occlusion of the IRA. The physician can hear an S4 with the meaning that the LV is stiff so there is a need for a stronger boost from a vigorous atrial contraction. The physician tries to listen to an S3 to see whether there is LV dysfunction. However, these S3 and S4 sounds are indirect and inconclusive signs. Further, there are no signs pointing to the event that an IRA is being recanalized.

If there is severe LV dysfunction, then there are signs pointing to the fact that the left heart system is overwhelmed, with low blood pressure (weak pulse), low cardiac output (vasoconstriction in the lower extremities), decreased urine output (in the renal system), and fluid overload (rales in lungs). The other signs of right heart failure are elevation of the jugular vein pulse and distention of the external jugular vein. The mechanisms and origin of the signs caused by the LV dysfunction after AMI are summarized in Table 1.7.

Table 1.7. Mechanism and Origin of Signs due to LV Dysfunction after AMI

	Index area	**Upstream to the index area**	**Downstream to the index area (system)**	**Downstream to the index area (network)**
	Left ventricle	Pulmonary vasculature	Aorta and distal vasculature	Renal vasculature
Mechanism of disease	Left ventricular failure	Fluid overload	Decrease blood pressure	Decrease blood pressure
Signs	S3	**Rales in lungs, Jugular vein distention**	**Decreased BP, distal vasoconstriction**	**Decrease urine output**

Data Mining (Work-up) In the example of a patient with ST segment elevation (STEMI) complicated by HF, an electrocardiogram (ECG) will document whether or not there is ST elevation in a 12-lead ECG. An ECG does not give exact information about the location, severity, and patency of the IRA. The ECG only reflects the electrical activities of the myocardium as a whole. A coronary angiogram will provide an exact location of the occlusion, its severity, and distal flow.

An ECG monitor in the intensive care unit will help to track the heart rate or simple or complex premature atrial or ventricular contractions (PAC or PVC) resulting from an increased compensatory sympathetic output by the upstream regulatory system of the heart.

Brain-type natriuretic peptide (BNP) level would tell us about the fluid status in the right atrium (upstream to the LV). In contrast, troponin and creatine phosphate kinase enzyme would tell us about the damage of the myocardium distal to the index lesion (downstream to the obstruction). There are no non-invasive tests to detect collaterals of the coronary arteries except the invasive coronary angiogram.

In order to assess the LV function, echocardiography would help to discern the LV or RV dysfunction, the wall motion abnormality, and valvular problems. A pulmonary catheter can measure the pressure in the left and right atrium and ventricle. (Table 1.8) All the possible tools to investigate the cardiac function for patients with LV dysfunction due to AMI based on a computational cardiac model are listed in table 1.8

Table 1.8. All Possible Tests for Patients with LV Dysfunction due to AMI Based on a Computational Cardiac model

	Area in Focus	**Direct Tests**	**Indirect Tests**
Coronary artery	Coronary artery index lesion (anatomy)	**Coronary angiogram**	**ECG** showing ST elevation
	Coronary artery	**Coronary**	**Fractional Flow**

	(flow)	**angiogram**	**Reserve**
Myocardium	Myocardial damage distal to the index lesion	**CK-MB, Troponin** elevation	**Echocardiography**: wall motion abnormality
Cardiovascular system	Left ventricular systolic function	Left heart catheterization: **LVEDP, echo. LVA**	
	Aorta	**Left heart catheterization:** AO pressure, BP	
	Pulmonary artery	**Right heart catheterization:** PA mean pressure	**Doper Echo: PA systolic pressure**
	Right atrium	**Right heart catheterization:** RA pressure	**Doppler Echo: RA systolic pressure**

LVEDP: Left ventricular end diastolic pressure, LVA: left ventriculogram, AO: Aortic, PA: pulmonary artery, RA: right atrium,

Management Based on a Computational Cardiac Model In the example of AMI, the main treatment is to open the IRA ASAP by fibrinolytic therapy or percutaneous coronary intervention (PCI) and to give antiplatelet or anticoagulant treatment if required. This is a therapy aimed directly at the root-cause problem. From the proximal end of the index lesion, because the IRA cannot deliver oxygen to the distal myocardium, it is necessary to decrease oxygen requirement by decreasing demand. This tactic can be implemented effectively by beta blockade while oxygen supplement by nasal cannula also intuitively helps. The intravenous (IV) nitroglycerin (NTG) decreases preload and thereby decreases oxygen as well. An intra-aortic balloon pump (IABP) works by increasing the blood pressure which hopefully improves the distal coronary perfusion.

At the distal segment of the IRA, nitroglycerin (NTG) tries to dilate the distal coronary arteries if the distal coronary vasculature is not at maximal vasodilation (which usually is). This is why NTG was never proven to decrease mortality or morbidity.

Coronary artery bypass graft surgery (CABG) works on the mechanism of work-around to bring the blood to the distal segment without correcting the index lesion.

Looking at the other systems of the body network, if there is lung congestion, the treatment includes relieving fluid congestion by IV diuretic. If there is respiratory failure, oxygen supplement, intubation, and mechanical ventilation is indicated while waiting for the LV function to recover.

During AMI, a patient can develop ventricular tachycardia (VT) or fibrillation (VF). If not treated accordingly, the patient can die (cardiovascular system shutdown). So in the case of VT and VF, synchronous electrical shock is the treatment of choice. An extrinsic electrical surge crosses the heart and wipes out all the electrical activities for 1or 2 seconds. After that, the heart recovers its intrinsic electrical activities and restarts them from their origin, the sinus node. From it, the electrical activity spreads out again on its regular grid. Using IT terminology, this is called system recovery.

A summary of all possible modalities of treatment for a patient with AMI complicated by HF according to a computational cardiac model are listed in table 1.9

Table 1.9 Classification of all Possible Modalities of Treatment for AMI and LV Dysfunction on a Computational Cardiac Model

	Main Area of interest	Proximal to the IRA	Distal to the IRA	Work-around configuration
CORONARY ARTERY				

Location	Index lesion at IRA	Prestenotic dilation	Post-stenotic Dilation	Collaterals
Target treatment	**PCI Antiplatelet**	**Increase perfusion by IABP**	**Nitroglycerin**	**Nitroglycerin**
Work-around	**CABG**	None	None	None
MYOCARDIUM				
Location	Not applicable	Myocardium in adjacent area	Myocardium supplied by the index lesion	
Target treatment		**Betablockade to decrease O2 demand, give O2 supplement**	**Betablockade to decrease O2 demand, give O2 supplement,**	None
Electrical System recovery	None	**Cardioversion if VT or VF**	**Cardioversion if VT or VF**	None
CARDIOVASCULAR SYSTEM				
Location	Left Ventricle	Pulmonary venous and arterial system, right ventricle	The aorta and peripheral vasculature	None identified yet
Target treatment	**Vasodilator Diuretic LVAD**	**Diuretic**	**Arterial dilator LVAD, IABP**	None
System replacement	**Cardiac transplant**	None	None	None

PRACTICAL APPLICATIONS

The HEAD-ON Approach

Difference Between the Clinical Approach and the New Method Using artificial intelligence methodologies to investigate and treat a CV problem is a new and innovative way to work with a same old object - the heart. During data collecting, mining, and management, the physicians are **PRO-ACTIVELY** looking for symptoms and signs based on a computational configuration of the cardiovascular system. The physicians have to pinpoint **EXACTLY** the symptoms and signs generated by the index problem or lesion. Which are the **DIRECT** tests proving the pathology of the index lesion or problem? Which are the direct treatments correcting the abnormality of the index lesion or problem? Then these questions are applied again on the 4 other areas of interest including (1) the area proximal and (2) distal to the index lesion or problem, (3) the work-around configuration (the bypass system), and (4) the other pulmonary, renal, or cerebral systems interacting with the cardiovascular system.

When searching for symptoms and signs, selecting tests or delivering treatment, the physicians need to confront the problem head-on, asking for the first hand data, analyzing the results of the direct tests and giving the treatment straight at the target. This approach can be done only after reviewing all the possible clinical scenarios provided by a computational cardiac map.

The example of the diagnostic, testing, and treatment process of a patient with aortic stenosis is summarized in table 1.10. What makes the table 1.10 special is that the empty cells are showing no identified data. This fact would stimulate more thinking and observation from physicians to look for new symptoms, signs, or modalities of treatment in the 7 areas of interest because "we only see what we are pro-actively looking for."

Table 1.10 Guide for Data Collecting, Mining, and Management of Aortic Stenosis based on a Computational Cardiac Model

		Area of interest	Upstream to the area of interest	Downstream to the area of interest	Work-around set-up	Other cardiovascular system

		Aortic valve	**Left ventricle**	**Aorta and peripheries**	**None identified**	Central nervous system
Data Collecting	**Symptom**	none	**SOB** because of pulmonary congestion, **Chest pain**	**Dizziness** because of low BP		**Syncope**
	Sign	**Systolic murmur at 2^{nd} R ICS**	**Rales** in lungs		None	None
Data Mining	**Direct tests**	**LHC echo, Doppler**	**Echo LHC**	**BP** measurement	None	**RHC**
	Indirect Tests	**None**	None	None	None	None
Management	**Target treatment**	**Percutaneous aortic valve stenting**	**Diuretic** to relieve congestion	**Vasodilator is contra-indicated**	None	**Dialysis** if renal failure
	Replacement	**Surgical aortic replacement**	None	None	None	None

This active search is very helpful and fruitful because the physician is following the investigative and treatment trail on a computational cardiac model. This is different than the passive way of asking questions for symptoms, looking for physical signs, and treating patients through a checklist handed down by and memorized from many previous generations of physicians.

Less Brain Cells for Storage, More Brain Cells for Thinking The new methodology is to investigate and treat a cardiac problem through a new computational configuration of the cardiovascular system. This would help the physicians to use less brain cells for storage and more for thinking. Our brain does not have enough chips to store all the data taught in medical school, which need to be updated constantly by new discoveries while purging the daily junk by which we are bombarded from print and electronic media. The physicians then formulate the opinions of their own brain cells combined with all the best output of a collective brain called “the artificial intelligence” which is graciously owned collectively by humankind. The advantages of the new thought generating process while using a computational cardiac model or map are listed in table 1.11.

Table 1.11 Advantages of the Use of a Cardiac Computational Model

1. Set up all the possible clinical scenarios on a computational cardiac model
2. Actively seeking symptoms, signs, and testing of the problems located on the 3 main areas (index, upstream and downstream) of a computational cardiac model
3. Actively looking at the symptom, sign of the work-around configuration
4. Clearly focus the treatment on each area of the computational cardiac model
5. No missing data and treatment
6. No need for checklist memorization

Critical Thinking and Clinical Judgement Computer technologies with AI help a lot in collecting, storing, sorting, processing, and analyzing data. They are extremely helpful in providing physicians with detailed information and fact (verified information). However, data and facts alone do not necessarily lead to solutions. It is the critical analysis of the facts that deliver the correct answers. Medical decisions are made on the basis of **critical thinking** and **clinical judgements** are based on the relevancy of the data collected. These medical decisions and clinical judgements are the results of the long thought process generated from formal learning, data from guidelines and practice standards, experience, an understanding of the incidence of disease in the population that the patient represents, the relationship of symptoms to specific disease states, and the likelihood of a disease being present in a specific patient.

Even so, at the end of each bedside encounter with a patient, it is the physician **alone** who makes a decision about what is relevant, and what is helpful to patients. These decisions come from wisdom and compassion which can only occur through experience and introspection, a unique human trait.

In this book, all the discussed strategies and tactics of data collecting, data mining, data converting, and management are applied in each chapter. At the beginning of each chapter there is a paragraph devoted to strategic programming, detailing the tactics used in the investigating process for that particular CV condition. Next to it, in the data colleting section, there is a paragraph detailing what to look for in the 7 areas of interest based on the computational cardiac model. Then at the beginning of each management section, there is a table pinpointing the available treatments in the 4 areas: data management, root-cause correction, work-around configuration, and system replacement.

In each chapter, all the possible aspects of a specific CV problem from symptoms, signs to testings and options in management based on a computational cardiac model are presented. This new view is challenging because it opens new doors and brings us to new horizons.

Conclusion Physicians are faced daily with the challenge of delivering the best care to patients with CV disorders. The expert physician integrates all of the information and each patient's unique status to decide the best investigative plan and therapy. In every case, thorough knowledge of the patient's history, and the examination, laboratory results, and imaging studies is essential for high-quality care.

In the new way of managing cardiovascular care, with the help of AI methodologies, physicians are able to navigate through a computational cardiac map that encompasses strategic programming for prevention, diagnosis, and treatment of heart disease in a clinical and cost-effective manner. With the time they save, the physicians can focus more on performance improvement and have quality time with family and society. The end result is to deliver the best, cost- and time effective quality cardiac care. These are the noble goals and tools for the delivery of quality cardiac care of the 21st century.

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