ECG INTERPRETATION USING 3D GRAPHICS

ECG Tech Training Software
for use with the 3D VCG from
Phipps and Bird

3D HEART: A NEW VISUAL AID FOR ELECTROCARDIOGRAPHIC ANALYSIS

Emergency medical personnel and primary care physicians are becoming increasingly limited in their ability to use the standard 12-lead electrocardiogram (ECG) to diagnose common cardiac abnormalities. The advent of newer methods and automated ECG analysis have de-emphasized inclusion of ECG mastery in training programs.

A spatial understanding of myocardial activation obtained via an instructional software program will improve the capability to:

1. Comprehend the relationship between the heart electrical activation waveform, the 12 lead ECG QRS complex and the associated vectorcardiogram (VCG),

2. Diagnose and locate a prior myocardial infarction or conduction disturbance from the VCG.

This new method is based on developing a sound understanding of the spread of the electrical excitation sequence through normal, infarcted myocardium (heart muscle).

THE 3D VECTORCARDIOGRAM

A quote from Chapter 4 of the current 'Marriott's Practical Electrocardiography'

> **"... the fundamental electrical process at the myocardial cellar level is the basis for all electrical information transmitted to the body surface. The three-dimensional vectorcardiogram (VCG) is closely related to and easily derived from the cellular activity making the diagnosis more intuitive and accurate."**
>
> by E. HARVEY ESTES, JR. et al.

The ECG-TECH Corp. has developed "The 3D Heart Program" that provides a simulation of the activation of the normal heart, the infarcted heart and the heart with conduction defects – LBBB, RBBB and anterior or posterior fascicular block.

ANATOMY OF THE HUMAN HEART

RIGHT ATRIUM

Receives venous return from the body via the superior and inferior vena cava

RIGHT VENTRICLE

Pumps blood to the lungs via the pulmonary arteries

LEFT ATRIUM

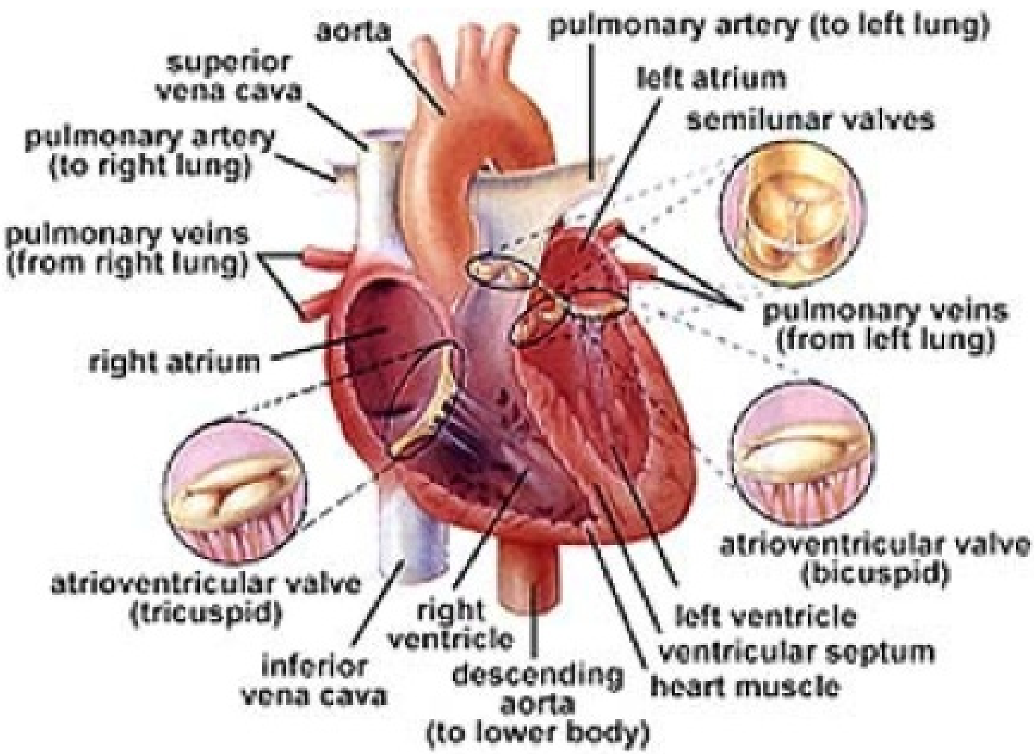
Receives the oxygenated venous return from the lungs via the pulmonary veins

LEFT VENTRICLE

Pumps blood to the body via the aorta

The left ventricle is the largest and most muscular heart chamber and pumps oxygenated blood to the body and its organs.

ANATOMY OF THE HUMAN HEART



THE HUMAN HEART

Right and left atria (RA and LA) and ventricles (RV and LV).

Inflow from the vena cavae to the RA, and from the pulmonary veins to the LA.

Atrial outflow to the ventricles across the indicated atrioventricular valves.

Outflow to the pulmonary artery from the RV and to the aorta from the LV across semilunar valves.

MYOCARDIAL CELL ACTIVATION AND CONTRACTION

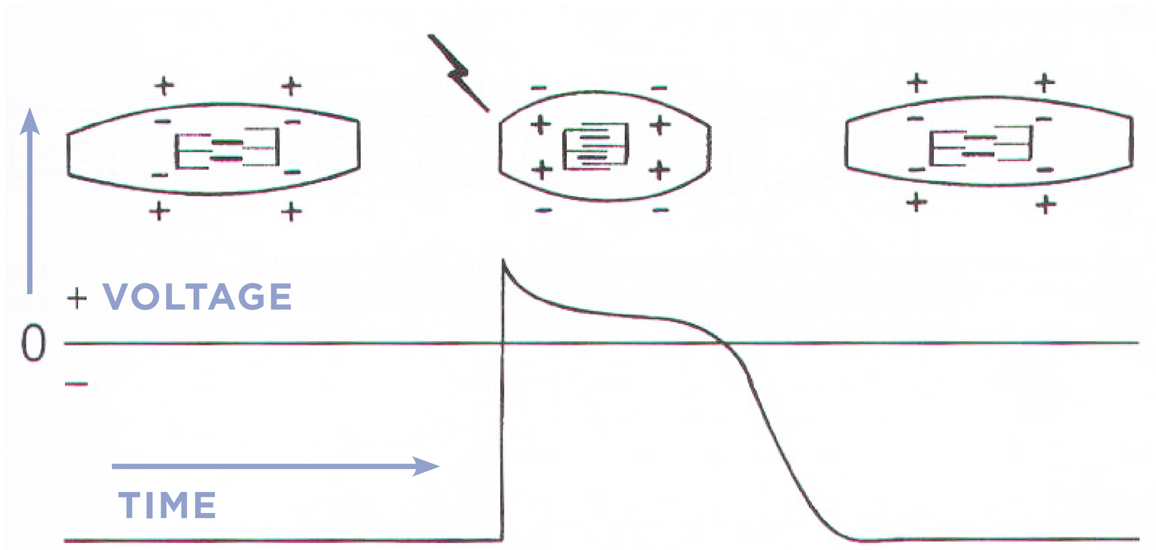
Individual chambers are composed of networks of discrete but coupled myocardial cells which contract and relax in sequence.

Myocardial cell contraction with sarcomeric shortening is initiated by electrical activation. Coordinated contraction within and between the chambers pumps blood from the ventricles to the pulmonary and systemic circulation.

Myocardial cell relaxation with sarcomeric lengthening permits the contracted heart chambers to enlarge and refill with blood.

MYOCARDIAL CELL ACTIVATION/DEPOLARIZATION AND REPOLARIZATION CYCLE

SHORTENING FOLLOWED BY LENGTHENING/RELAXATION



At the top a single cardiac cell is shown at three points in time:

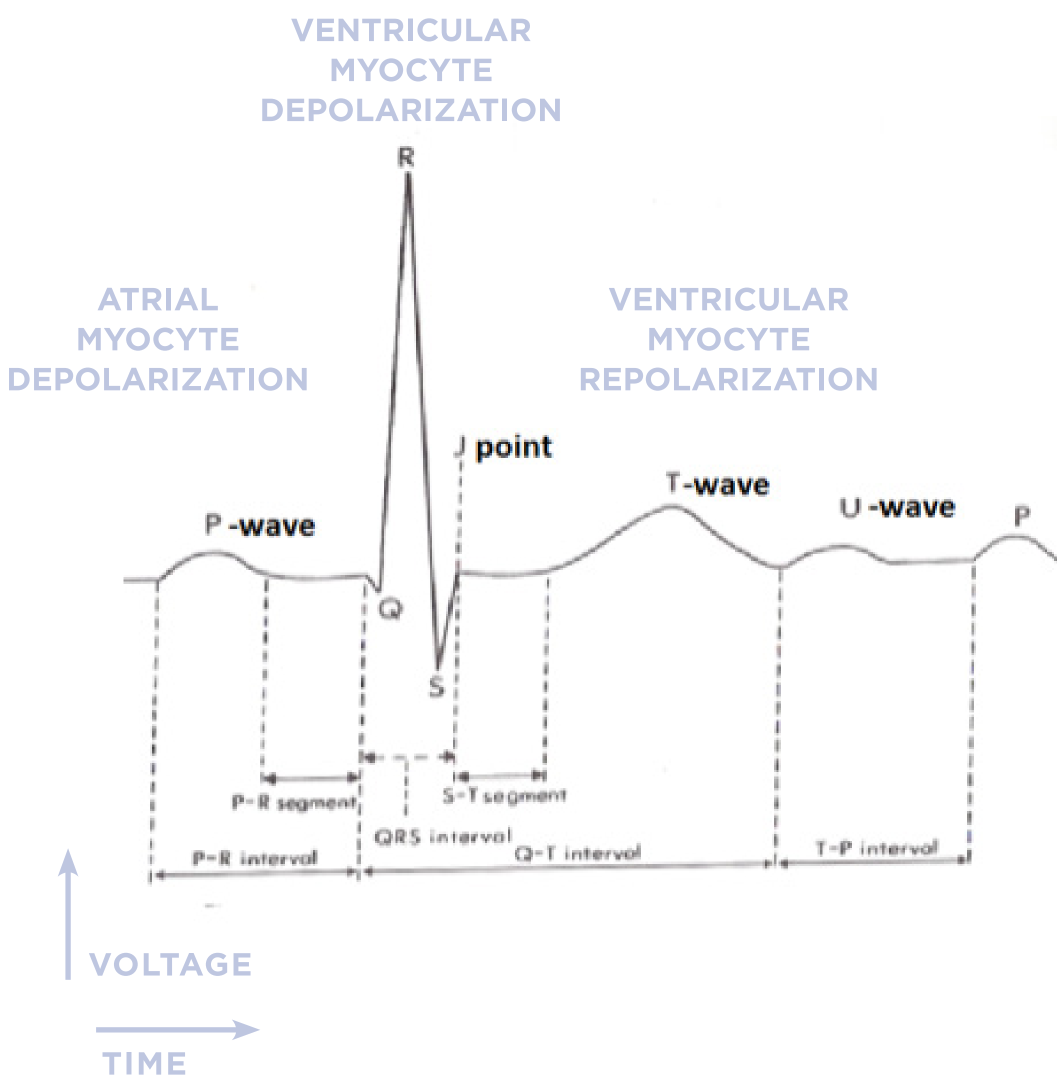
1. **Initially relaxed and polarized; sarcomere extended**

2. **Activation/depolarization (lighting bolt) by an impulse from an adjacent cell causing positive (+) ions to enter the cell;** sarcomere shortens

3. **Relaxed again after repolarization;** sarcomere re-extends
   The tracing at the bottom shows the electrical potential inside the cell.

STANDARD REPRESENTATION OF THE CARDIAC CYCLE

SUMMATION OF INDIVIDUAL MYOCARDIAL CELL CYCLES



COMPONENTS

P-WAVE
atria activation

QRS-WAVE
ventricle activation

T-WAVE
repolarization of the ventricles

U-WAVE
not normally present but related to repolarization

THE SPREAD OF ACTIVATION THROUGH THE MYOCARDIUM

The SA node spontaneously depolarizes to initiate the cardiac cycle. **The right atrium myocardium conducts the impulse to the left atrium and the AV node**

The AV node transmits the electrical impulse to the bundle of His which connects to the right bundle branch (RBB) and left bundle branch (LBB) at the superior margin of the muscular interventricular septum. The bundle branches distribute the impulse to the right and left ventricles (RV and LV). Each terminates on Purkinje fibers which interface with and activate ventricular myocytes.

This portion of the cardiac cycle is represented by the P-wave and the PR segment on the standard ECG.

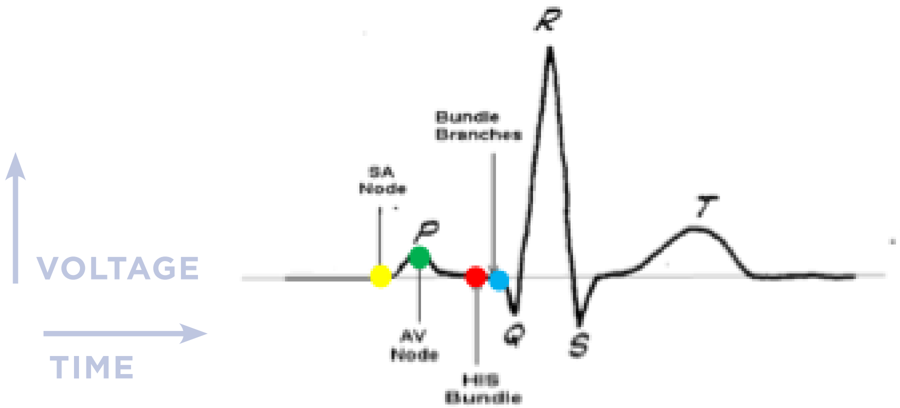
THE SPREAD OF ACTIVATION THROUGH THE MYOCARDIUM (CONTINUED)

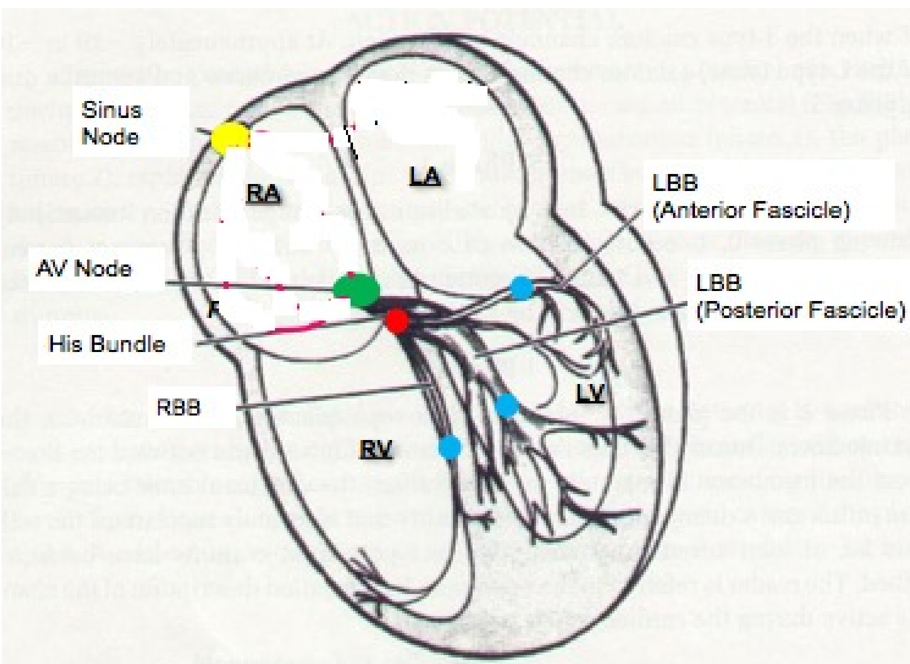
Cardiac myocytes located on the endocardium (inner surface) are activated by Purkinje fibers. They in turn activate adjacent myocytes and propagate the activation wavefront through the myocardium. The activation wavefront ends on the epicardium (outer surface). This results in coordinated myocyte contraction from endocardium to epicardium and apex to base.

Conversely and counterintuitively, myocardial cell repolarization followed by cardiac muscle relaxation proceeds from the epicardium to the endocardium.

This portion of the cardiac cycle is represented by the QRS complex and T wave respectively.

THE SPREAD OF ACTIVATION THROUGH THE MYOCARDIUM (CONTINUED)

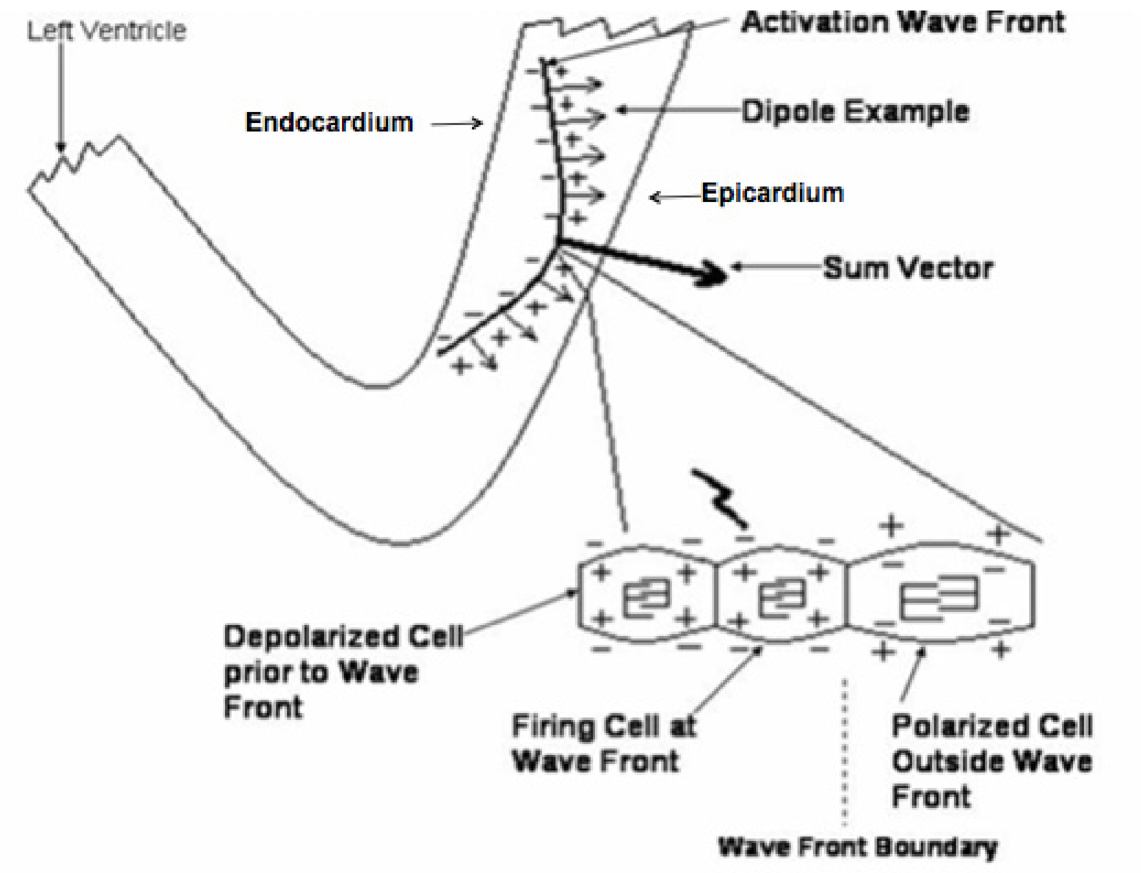




The heart activation sequence from the beginning of the P-wave to the beginning of the QRS complex is indicated by an ECG tracing and a four chamber view of a sectioned heart. The electrical impulse arising in the SA node (yellow dot) is conducted to the left atrium through Bachman's bundle and through internodal pathways (Anterior, Medial and Posterior) to the AV node (green dot). After delayed transit through the AV node and the bundle of His (red dot), the impulse enters the bundle branches (LBB and RBB, blue dots) for distribution to the terminal Purkinje fibers located in the endocardium of the ventricles.

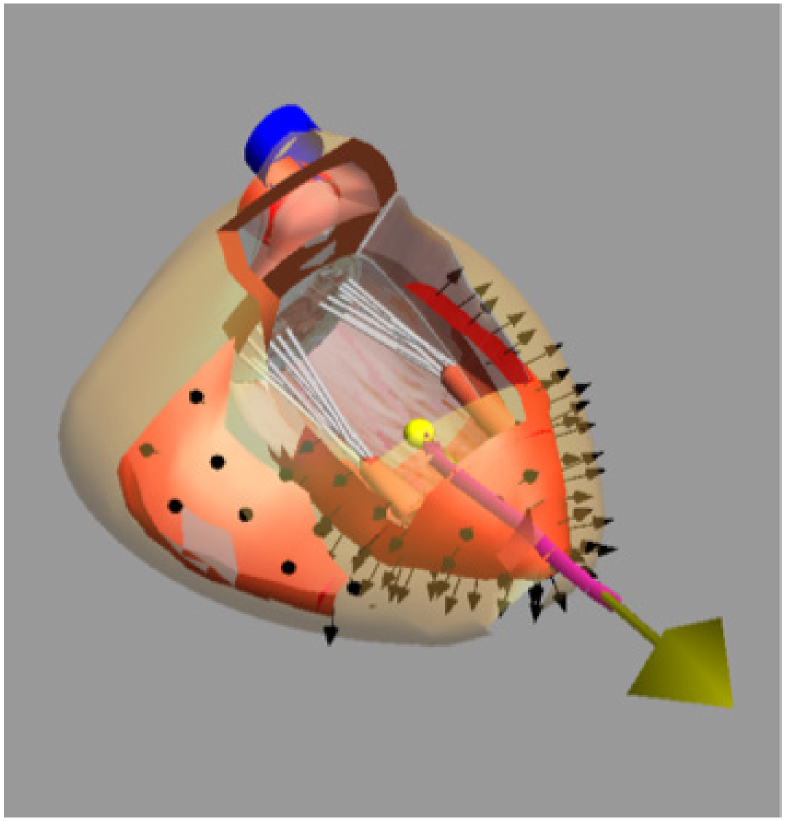
GENERATING THE QRS DIPOLE SUM VECTOR

ACTIVATION SURFACE AT THE BOUNDARY BETWEEN DEPOLARIZED CELLS AND POLARIZED RESTING CELLS



Note that the dipole vectors originate in the area of extracellular negative charge (activated myocytes) and point toward an area of extracellular positive charge (resting or repolarized myocytes).

THE GENERATION OF A SUM VECTOR FROM THE ACTIVATION SURFACE DIPOLE VECTORS AT THE MIDPOINT OF THE QRS



The sum vector, depicted by the gold arrow, represents the sum of the myriad smaller segmental vectors. The latter represent the sum of the individual myocyte dipole vectors within the segment.

Note that segment vectors of equal magnitude on opposing walls of the ventricles cancel each other. As a result, the sum vector points inferiorly and leftward.

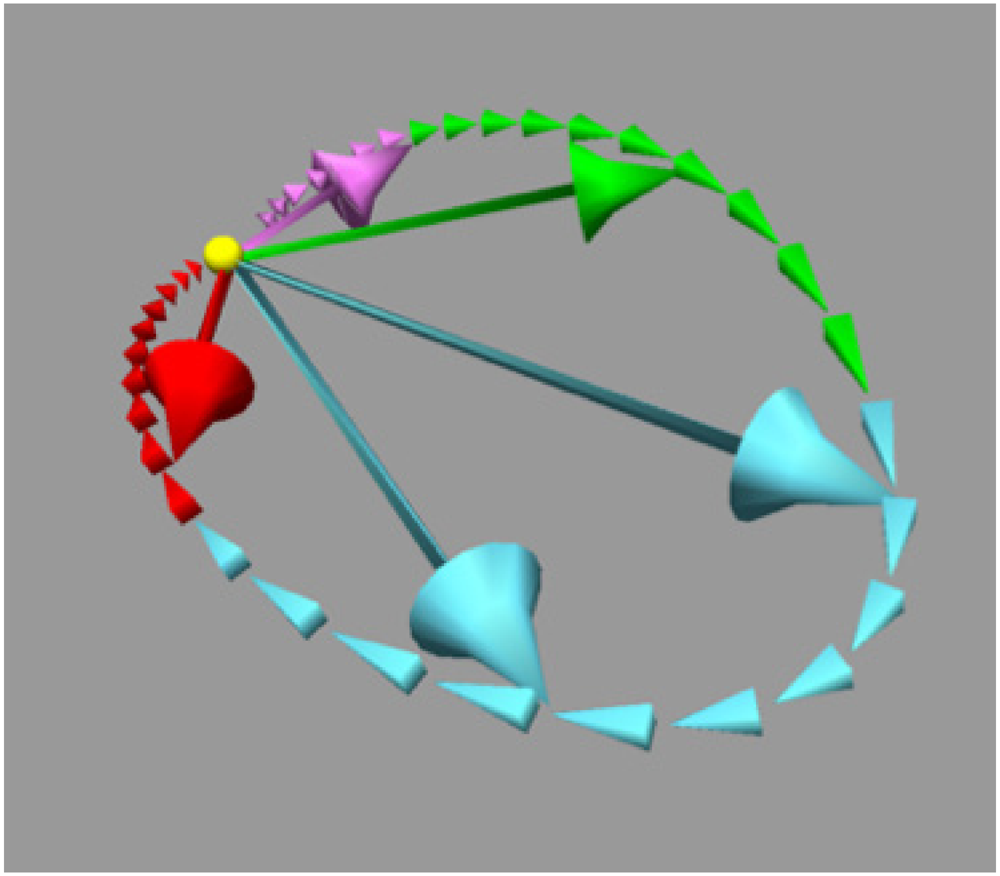
NORMAL 3D QRS SUM VECTOR LOOP

The instantaneous segment vectors, shown in black on the previous slide, add to generate the sum vector. The sum vector is proportional to the size of the associated activated surface, shown in red.

The activation surface spreads symmetrically from an initial band located at the base of the papillary muscles (red cylinders tethered to the mitral valve). This results in a **planar sum vector loop** oriented parallel to the long axis of the heart and perpendicular to a line between the papillary muscles.

The sum vector plane also exhibits symmetry about the maximum QRS sum vector. This vector normally points inferiorly in the frontal plane and posteriorly in the horizontal plane.

THE QRS SUM VECTOR LOOP



This figure shows the sum vector at five selected time points during the QRS portion of cardiac cycle. Note that the QRS might have been divided into 100 time intervals. Each interval would then have a sum vector of indicated magnitude and direction. As can be seen, connecting the tips of the sum vectors generates a loop which returns to the point of origin of the cycle. In this case, the QRS is 80 milliseconds in duration.

COLOR CODE

- 0 to 20 ms
- 20 to 40 ms
- 40 to 60 ms
- 60 to 80

GENERATION OF 3D VECTORCARDIOGRAMS

THE QRS AND THE LEFT VENTRICLE

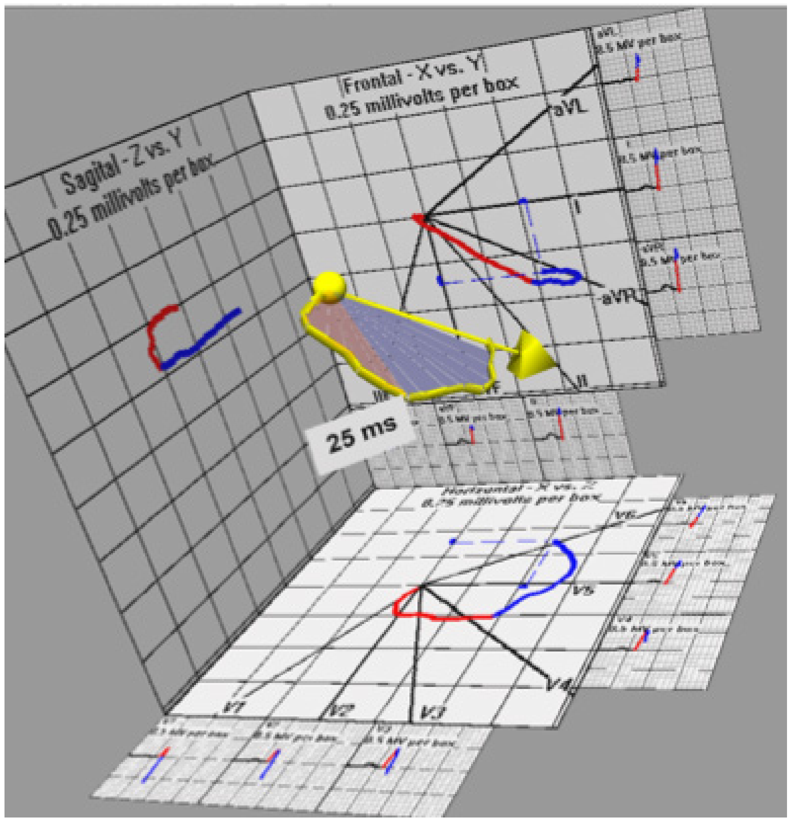
The left ventricle is the largest of the four heart chambers and generates the majority of the of the ECG QRS and T wave signals.

The anatomic long axis of the left ventricle of the average human heart is oriented 40 degrees inferiorly in the frontal plane and 30 degrees anteriorly in the horizontal plane.

It is convenient to consider the ECG signals as three dimensional vectors with an origin at the electrical center of the left ventricle.

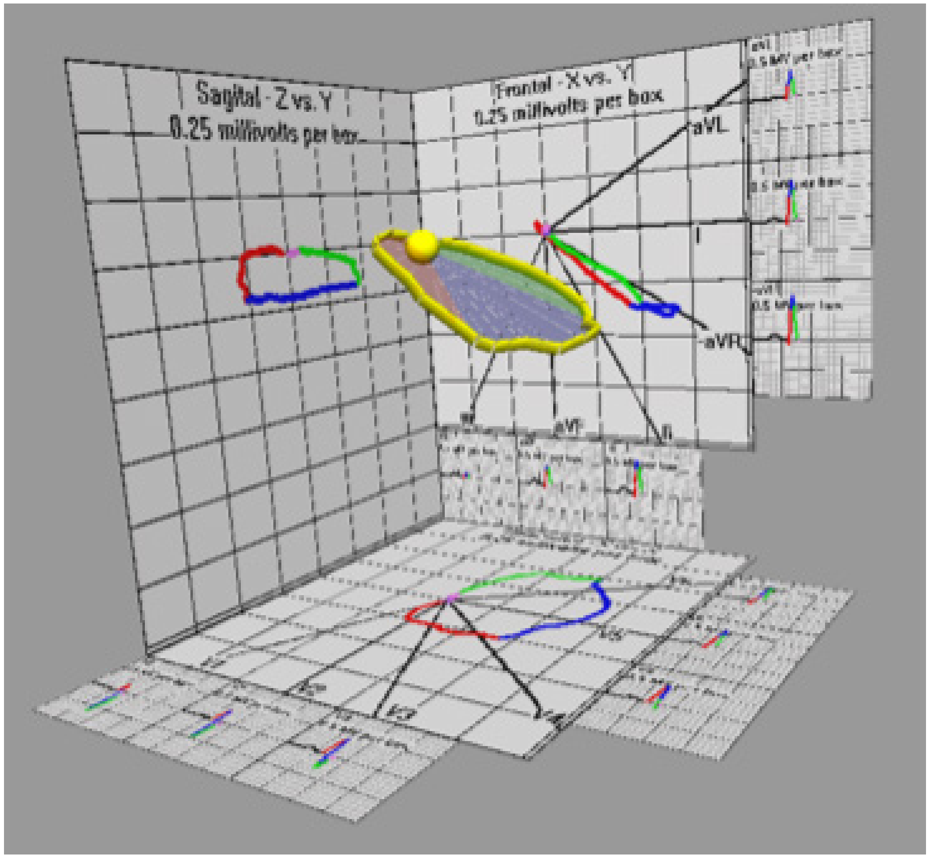
A 3D x,y,z coordinate system with origin at the electrical center of the left ventricle arrays the QRS vectors in a plane with a maximum vector oriented inferiorly in the frontal plane and posteriorly in the horizontal plane.

THE 3D QRS VECTOR IN TRANSIT



The diagram on the left shows the sum vector at the origin of a 3D coordinate system(x,y,z). Prior sum vectors are indicated by white lines in the time intervals colored red and blue. The sum vectors are projected onto 3 planes and from there onto the 12 lead ECG leads (see below) shown at the edge of the frontal and horizontal planes. Each color is 25 msec in duration and is divided into ten 2.5 msec intervals.

3D QRS VECTOR LOOP



The vectors start at the gold ball and point in the direction of the gold ring. Note that the QRS portion of the ECG waveform begins and ends at the origin (zero potential shown as a bright yellow sphere). Thus, the QRS vector trajectory forms a loop in 3 dimensions.

COLOR CODE

- 0 to 20 ms
- 20 to 40 ms
- 40 to 60 ms
- 60 to 80

12 LEAD ELECTROCARDIOGRAM ACQUISITION

Two sets of leads attached to the patients skin are used to record the ECG: the four limb leads and the six precordial or chest leads.

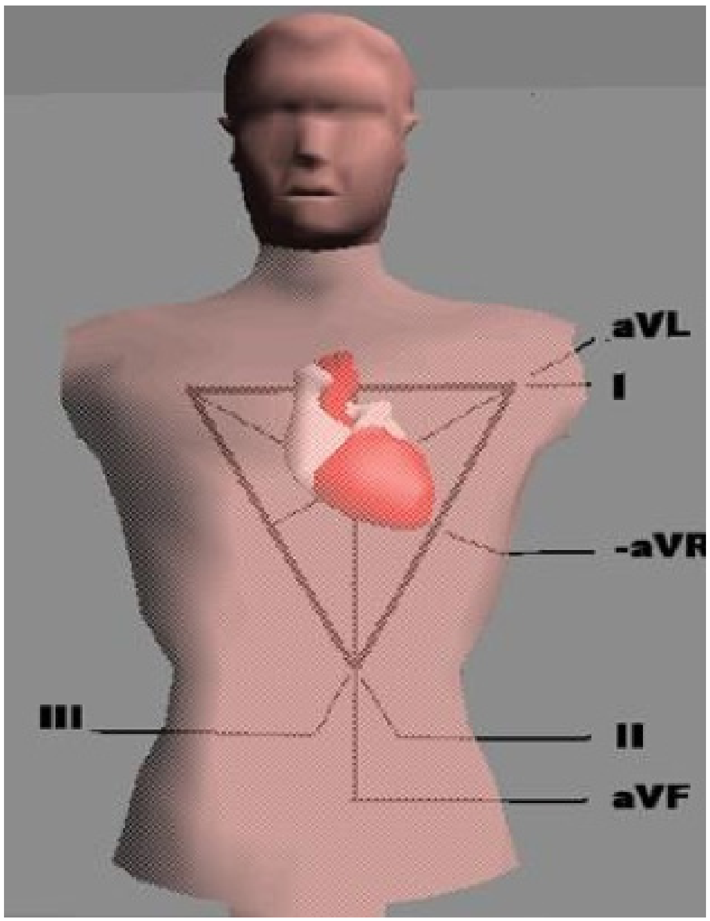
The limb leads are attached to the wrists and ankles and record heart signals in the frontal plane. The limb leads are represented by **I, II, and III** and **aVF, aVL and aVR** on the standard 12 lead ECG tracing.

The precordial leads are attached to the chest wall and record heart signals in the horizontal plane. The precordial leads are represented by **V1** through **V6** on the standard 12 lead ECG tracing.

LIMB LEADS DISPLAY VECTORS IN THE FRONTAL PLANE

SUPERIOR

RIGHT



LEFT

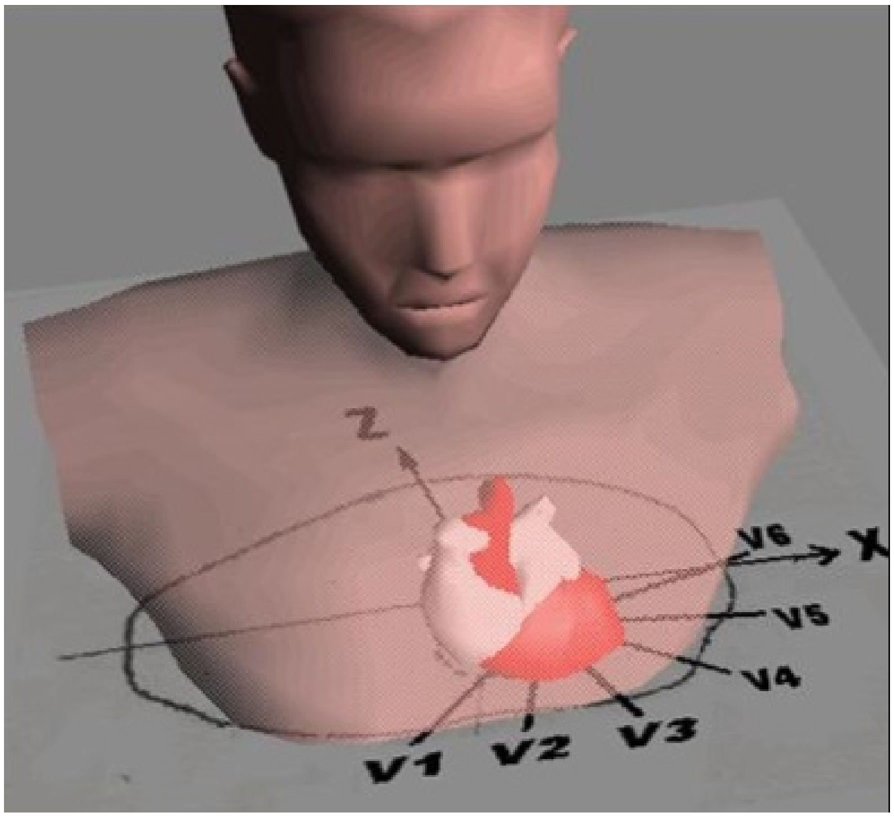
INFERIOR

The limb leads are superimposed on a heart anatomically placed in an idealized human torso. The orientation of the associated lead vectors in the xy frontal plane is shown. They all project from the electrical center of the heart and the amplitude of the instantaneous dipole sum vector in a given lead varies with lead orientation.

PRECORDIAL LEADS DISPLAY VECTORS IN THE HORIZONTAL PLANE

POSTERIOR

LEFT

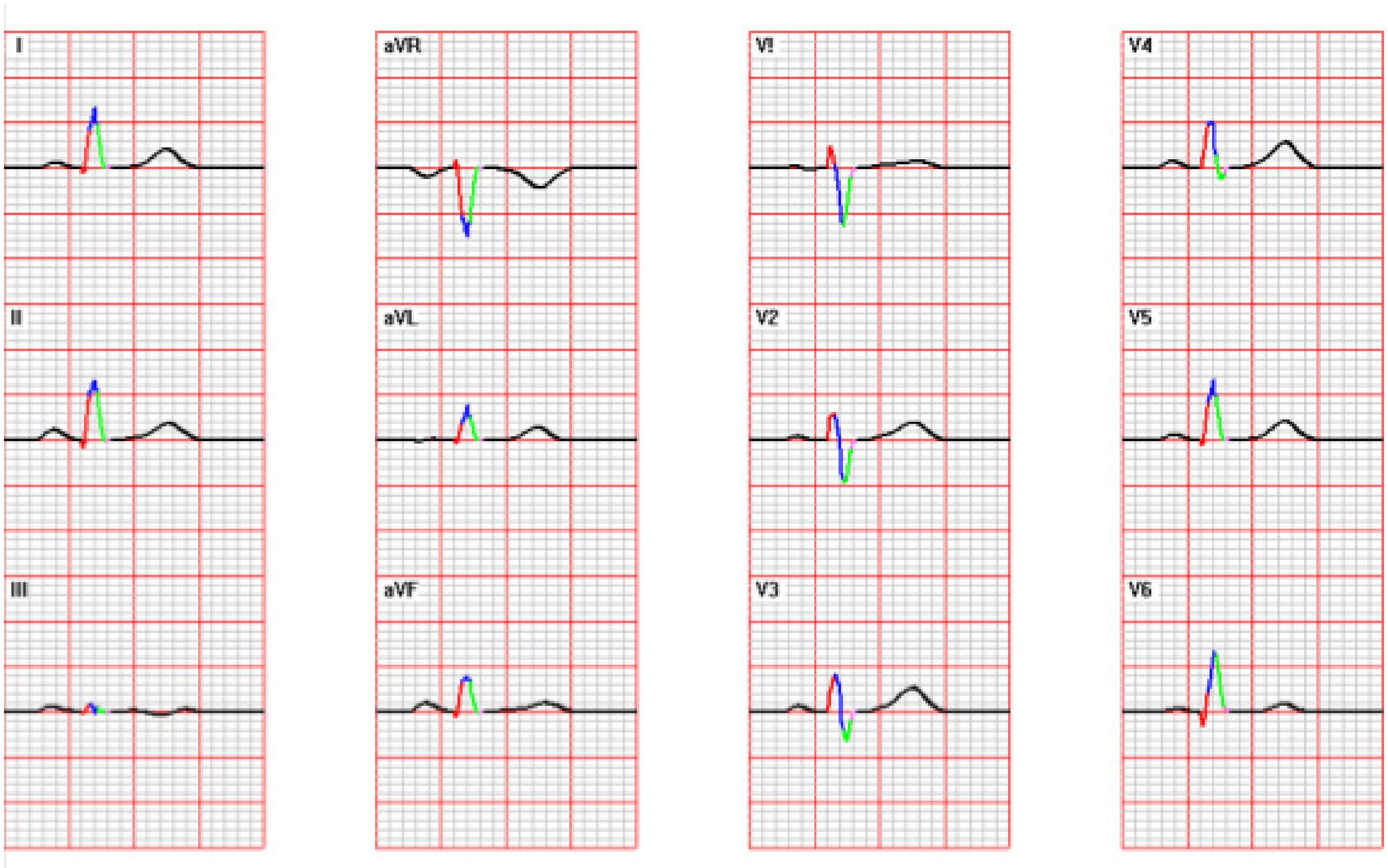


RIGHT

ANTERIOR

The precordial leads are superimposed on the same anatomically placed heart. The orientation of the associated lead vectors in the xz horizontal plane is shown. As before, the amplitude of the instantaneous dipole sum vector in a given lead varies with lead orientation.

STANDARD 12 LEAD ECG



COLOR CODE

- 0 to 20 ms
- 20 to 40 ms
- 40 to 60 ms
- 60 to 80

NEW VISUAL 3D VECTOR LOOP METHODS

3 D illustration of the loop created by the sum vectors generated during the activation process.

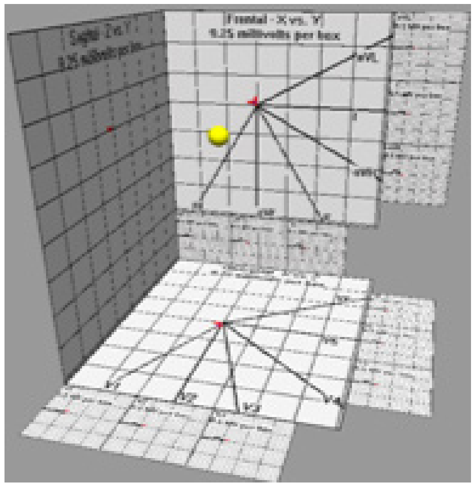
Illustrations of the projection of the 3D vector loop onto the ***frontal*** and the ***horizontal*** planes.

Derivation of limb lead tracings from the frontal plane vector loop projection and precordial lead tracings from the horizontal plane vector loop projection.

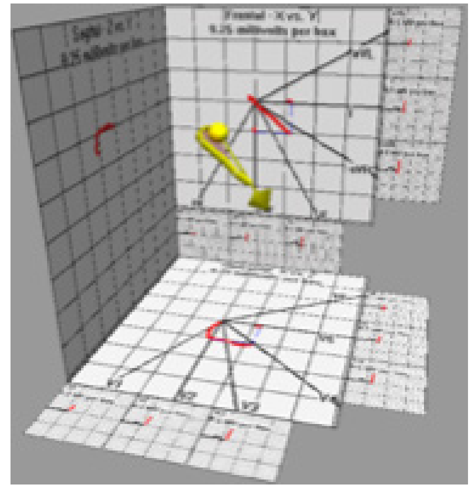
3D vector illustrations are used to improve the understanding of how myocardial infarctions of various sizes in various locations and conduction disturbances effect both the 3D vector loop and the 12 lead ECG.

3D DISPLAY OF THE QRS VECTOR LOOP

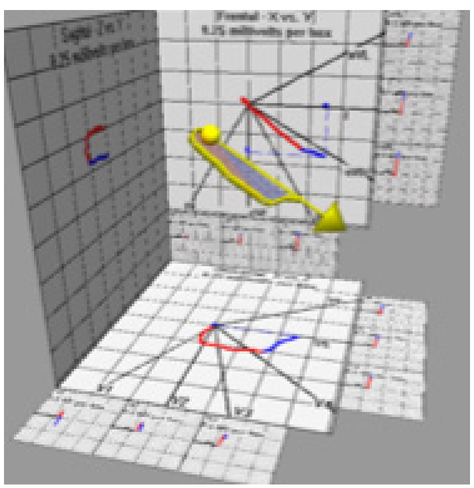
AT 5 MSEC
VECTORS ARE VERY SMALL.



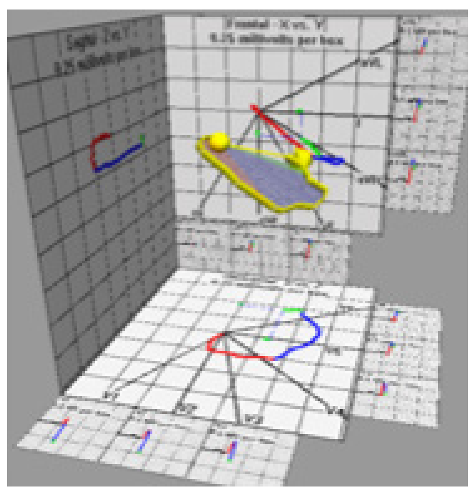
AT 25 MSEC
THE VECTORS POINT ANTERIORLY



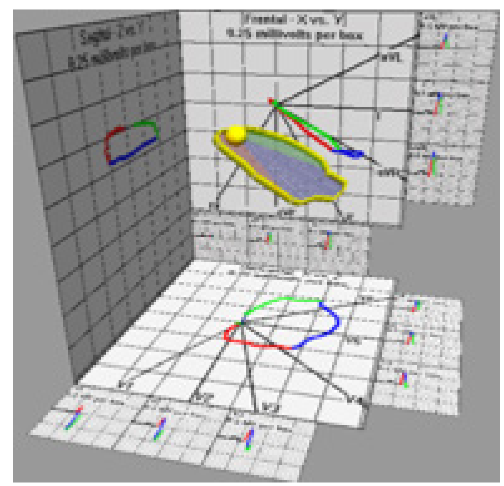
AT 50 MSEC
THE VECTORS ARE NEAR MAXIMUM AND POINT POSTERIORLY AND LEFTWARD



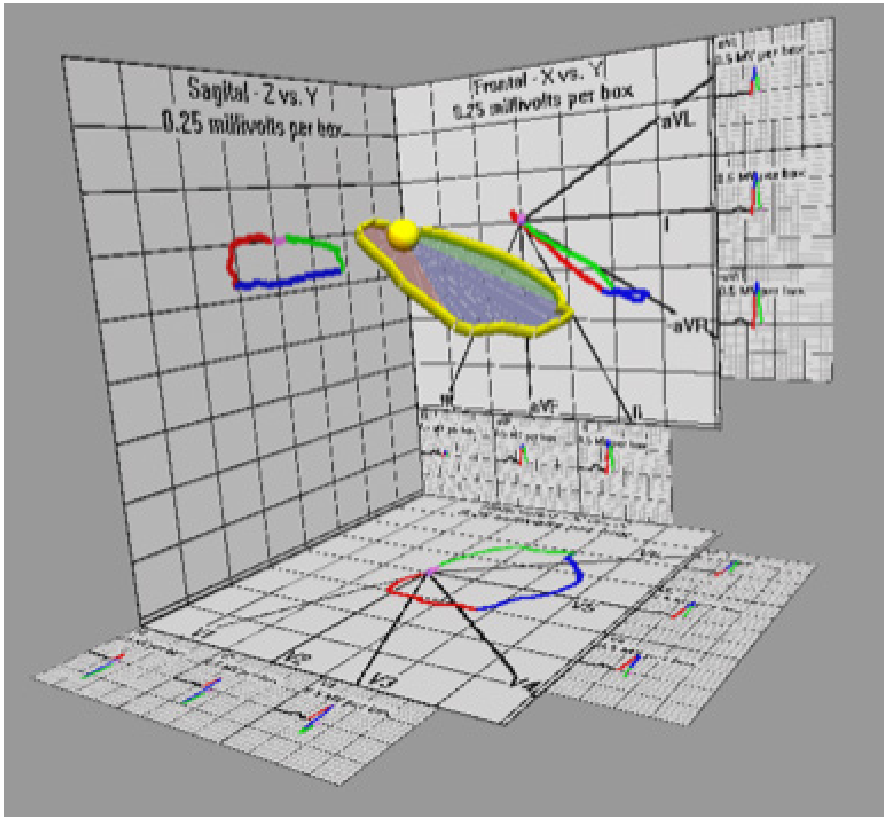
AT 75 MSEC
THE VECTORS POINT POSTERIORLY



AT 100 MSEC
THE QRS IS COMPLETE



RECOGNIZING DISTORTIONS OF THE QRS VECTOR LOOP IS KEY TO DIAGNOSIS

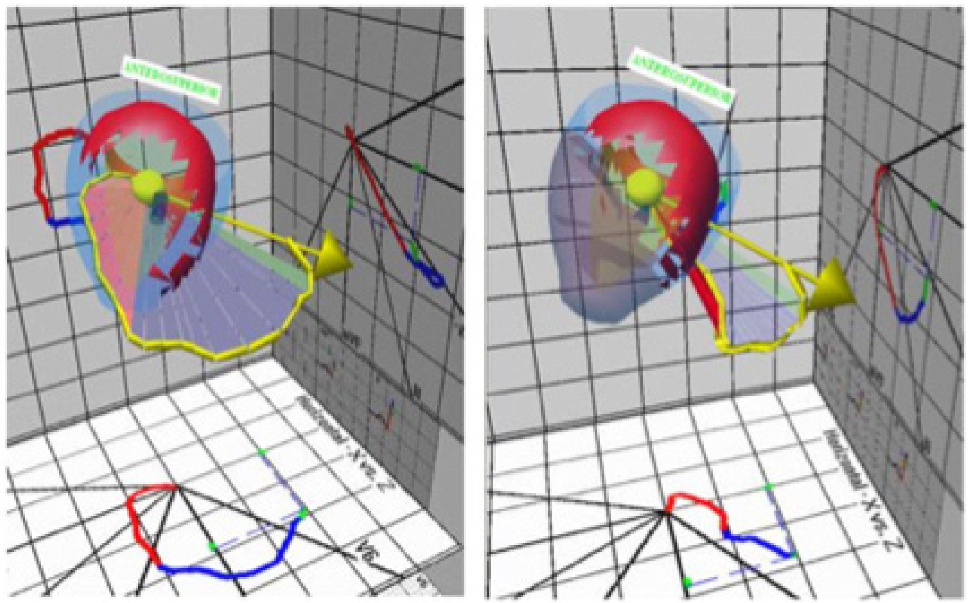


Note that the QRS portion of the normal VCG vector loop lies in a single plane.

An infarction or a delay in the normal excitation process results in a distortion or displacement of this plane and is readily recognized.

This distortion manifests in only a select number of contiguous leads in the associated 12 lead ECG tracing. However, pathologic 12 lead ECG changes are easily anticipated from alterations in the VCG vector loop.

PRECORDIAL LEADS DISPLAY VECTORS IN THE HORIZONTAL PLANE



Normal Heart Medium Anterior MI

An anterior wall MI results in the loss of the contribution of early anteriorly oriented myocardial cell dipole vectors to the sum vector. Consequently, the sum vector is displaced posteriorly, as seen in the horizontal plane, and inferiorly, as seen in the frontal plane (red and blue segments).

The shaded area of myocardium (right) indicates the zone of infarction. The red area(s) represents the activation surface(s) at same time point in both the normal and infarced hearts. The associated sum vector(s) are in gold. Note that the sum vectors have similar directions and magnitudes at the midpoint of the QRS yet have markedly different trajectories.

3D VCG IDENTIFICATION OF PATHOLOGY

Normal activation and myocardial infarction

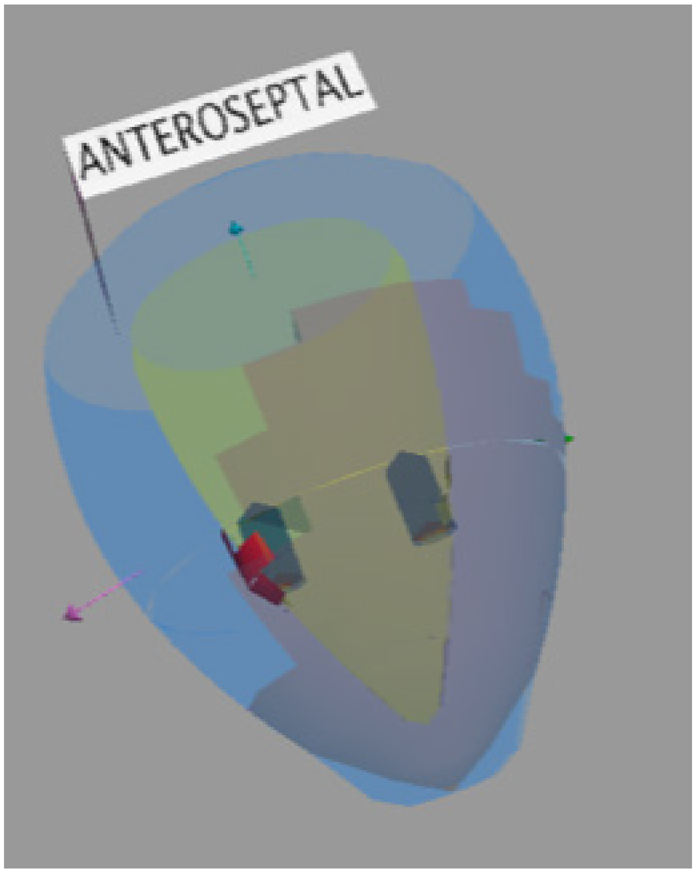
Large, medium, and small anterior MI

Large, medium, and small posterior MI

Large, medium, and small inferior MI

Conduction disturbances – left bundle branch block, right bundle branch block, left anterior fascicular block and left posterior fascicular block

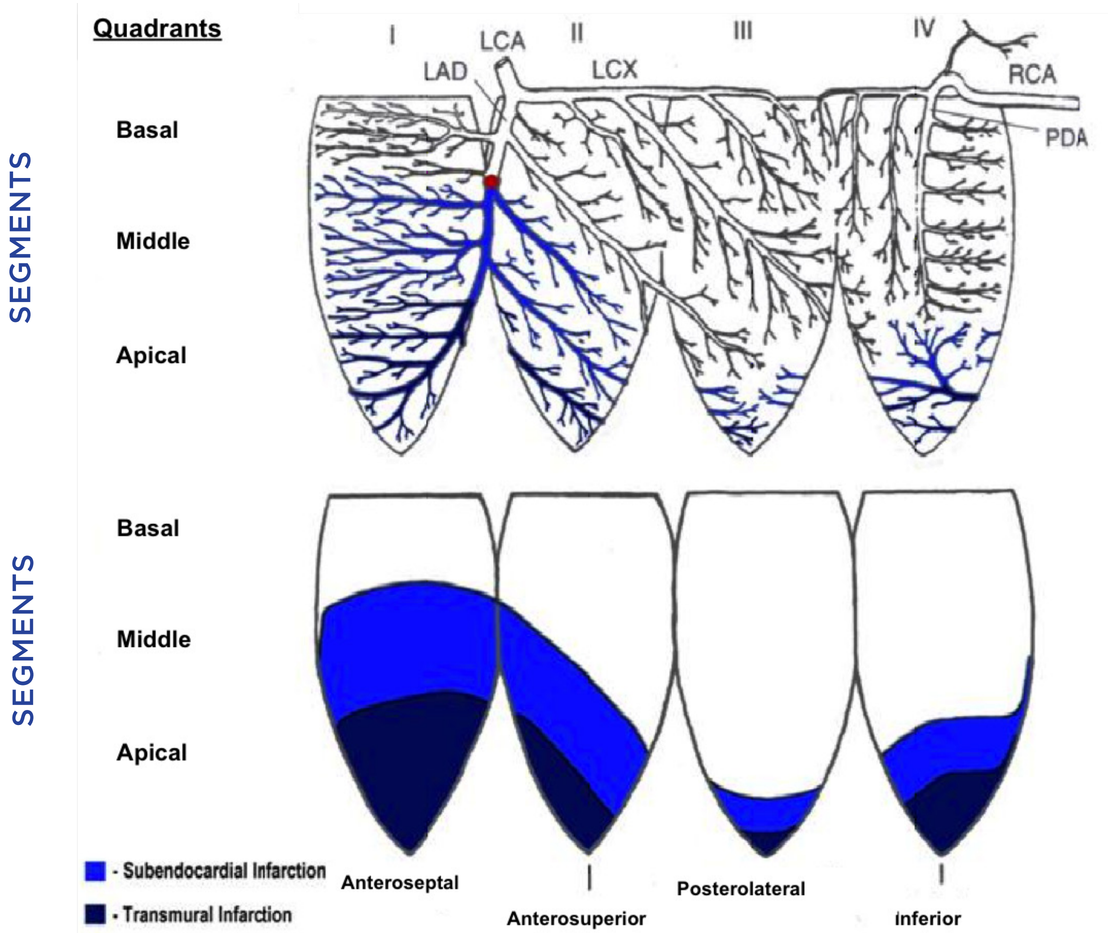
MYOCARDIAL INFARCTION
MEDIUM ANTERIOR WALL MI (AMI)



The septal (left, medial) and posterior free wall (right, lateral) boundaries of the anterior wall of the left ventricle are represented in blue. The shaded area indicates the location of the infarction. The scar tissue that replaces infarcted myocardial cells is electrically silent. As previously mentioned, the loss of anterior wall activated myocardial cell dipole vectors deflects the early sum vectors posteriorly in the horizontal plane.

CORONARY ARTERY PERFUSION

MERCATOR PROJECTION OF LEFT VENTRICULAR QUADRANTS



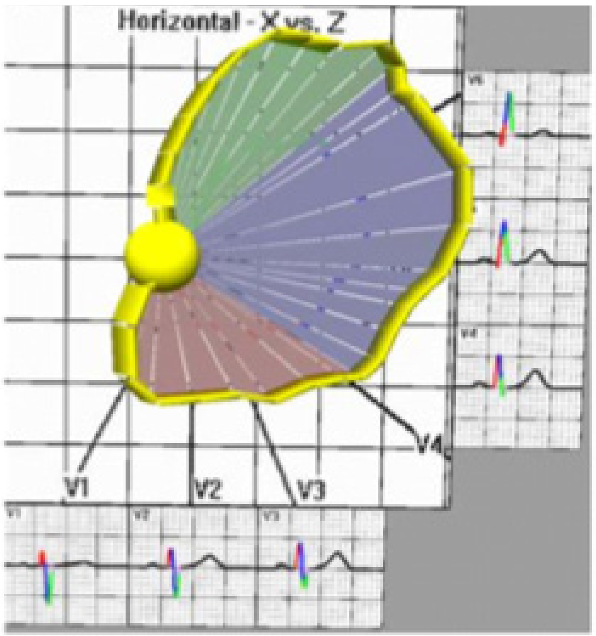
The mercator projection of the surface of the left ventricle (LV) is shown. The top shows the distribution of the coronary arteries that supply the LV. A **medium anterior wall MI** is indicated by an occlusion (red dot) of the ***left anterior descending coronary artery (LAD)***. The bottom diagram shows the same quadrants and differentiates regions of transmural infarction (full wall thickness - dark blue) from regions of subendocardial infarction (partial wall thickness-light blue). Note the involvement of the apical segment in all four quadrants.

LCA: Left coronary artery
LCx: Left circumflex artery
PDA: Posterior descending artery
LAD: Left anterior descending artery
RCA: Right coronary artery

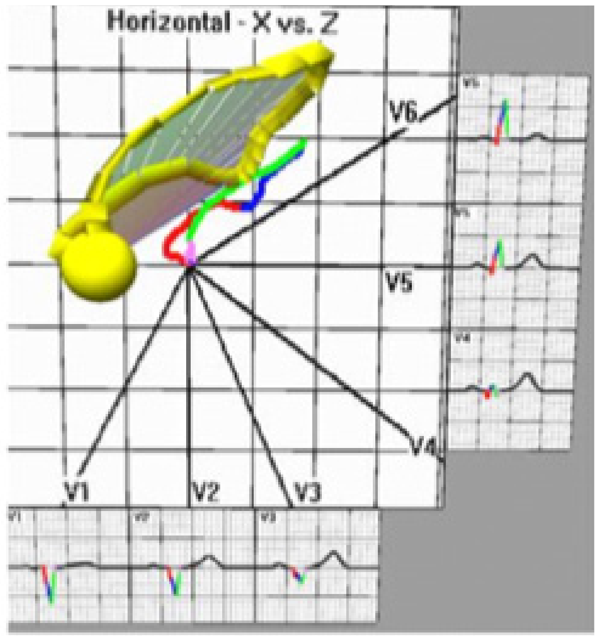
AMI DISTORTION OF THE 3D VCG LOOP

PROJECTION IN THE HORIZONTAL PLANE AND PRECORDIAL LEAD TRACINGS

NORMAL HEART



MEDIUM ANTERIOR MI



COLOR CODE

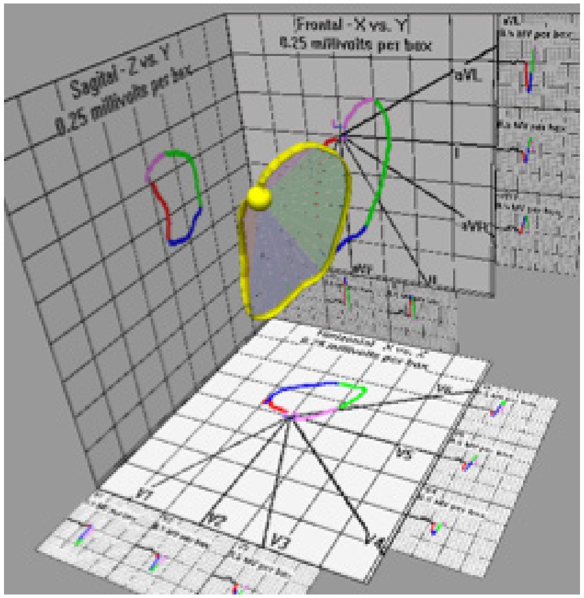
- 0 to 20 ms
- 20 to 40 ms
- 40 to 60 ms
- 60 to 80

The 3D vector loops generated by a normal heart and a medium anterior wall infarcted heart is seen from above. Sum vectors within the color coded time intervals are indicated by white lines. An AMI results in the posterior and inferior deflection of initial sum vectors, markedly distorting the normal anterior to posterior planar sweep in the horizontal plane. The posteriorly directed horizontal plane sum vector components result in Q waves in leads V1 to V4.

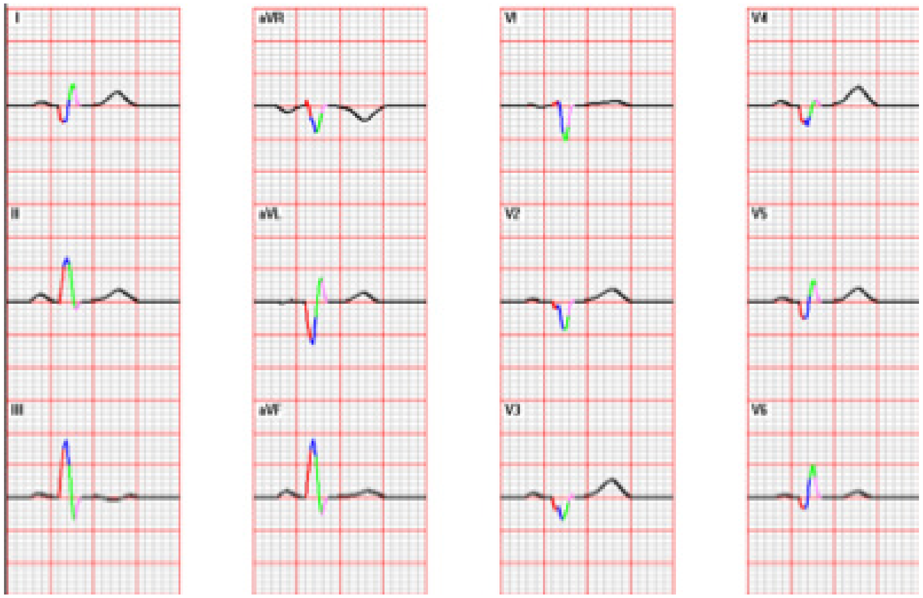
LARGE ANTERIOR WALL MI

A large anterior wall MI is readily recognized by the deflection of initial sum vectors posteriorly in the horizontal plane, leftward in the frontal plane and inferiorly in the sagittal plane. As a result, the 3D vector loop orients vertically, parallel to the sagittal plane (below left). The 12 lead ECG displays Q waves in precordial leads V2 through V6 (horizontal plane) and limb leads I and aVL (frontal plane). The proximal LAD occlusion is identified in a mercator projection on a later slide.

LARGE ANTERIOR WALL MI VCG



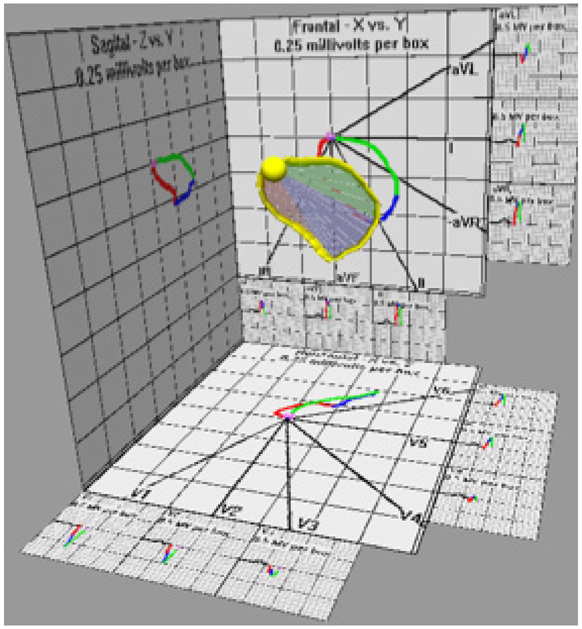
LARGE ANTERIOR WALL MI ECG



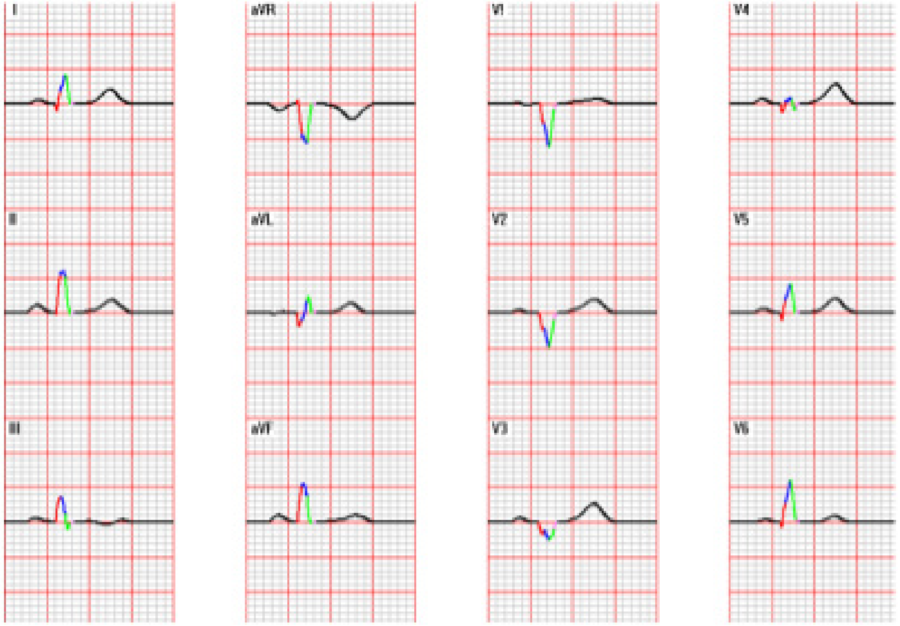
MEDIUM ANTERIOR WALL MI

As before, the initial vectors are displaced posteriorly (horizontal plane) and inferiorly (frontal plane), distorting the normal 3D vector loop. Here, as expected, the 12 lead ECG displays Q waves in leads V1 – V3 and leads I and aVL. The mid LAD occlusion is identified on a later slide.

MEDIUM ANTERIOR WALL MI VCG



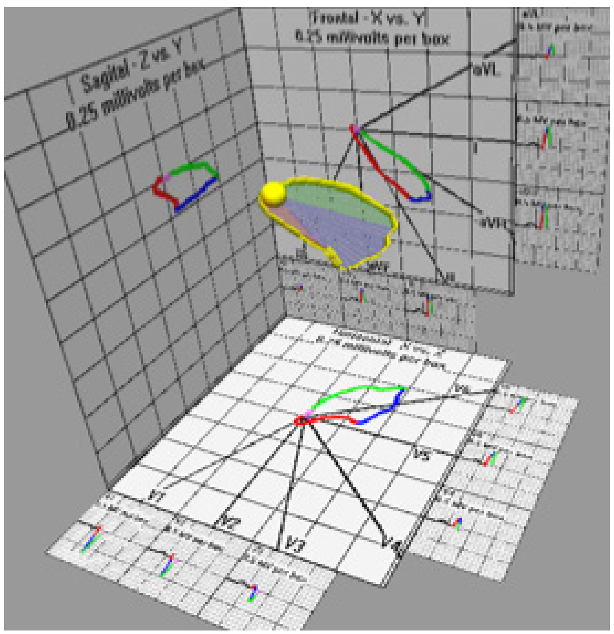
MEDIUM ANTERIOR WALL MI ECG



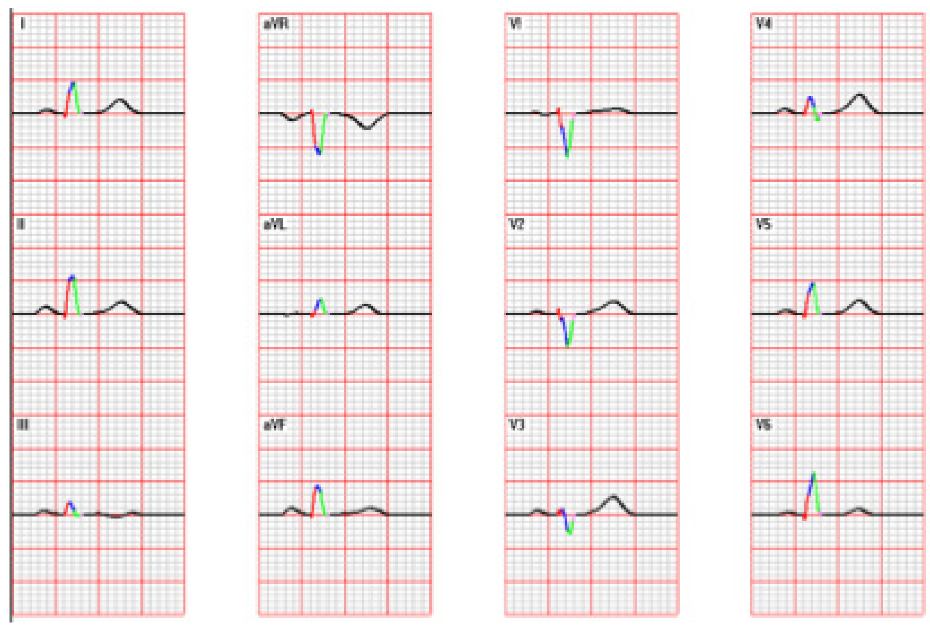
SMALL ANTERIOR WALL MI

The significant posterior and leftward deflection of the early (red interval) vectors in the loop diagram and presence of Q waves in leads V1, V2 and V3 in the ECG are indications of a small anterior MI. Some cardiologist may require the absence of initial R waves in V1 and V2 making this diagnosis difficult. The distal LAD occlusion is identified on a later slide.

SMALL ANTERIOR WALL MI VCG

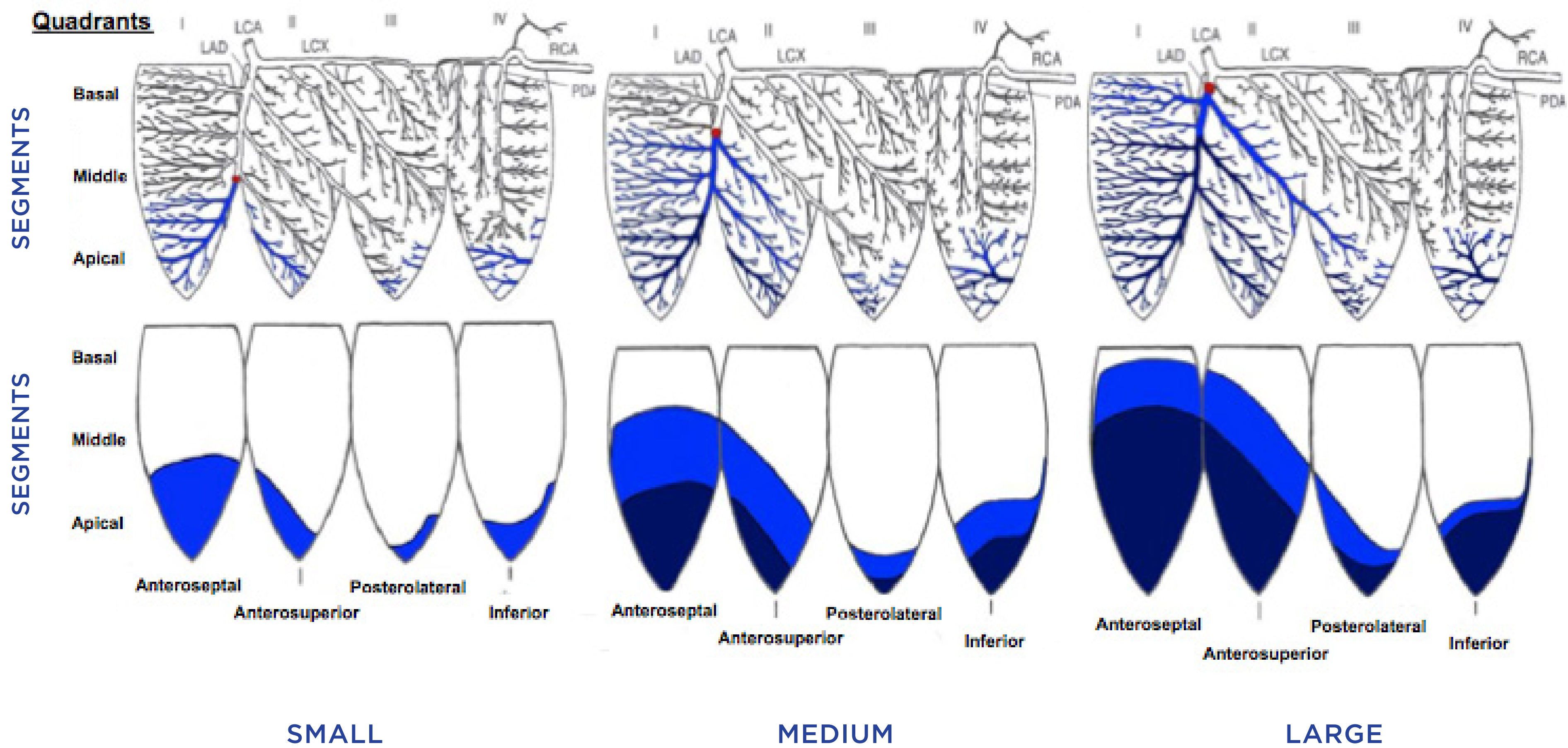


SMALL ANTERIOR WALL MI ECG



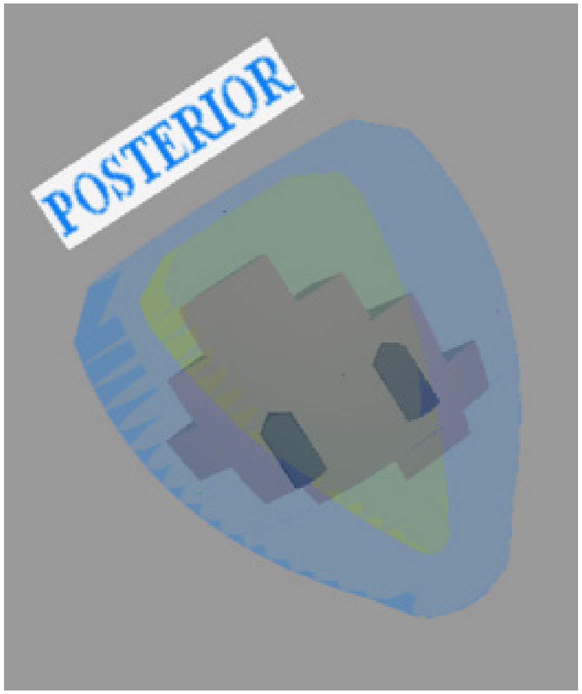
ANTERIOR WALL MI

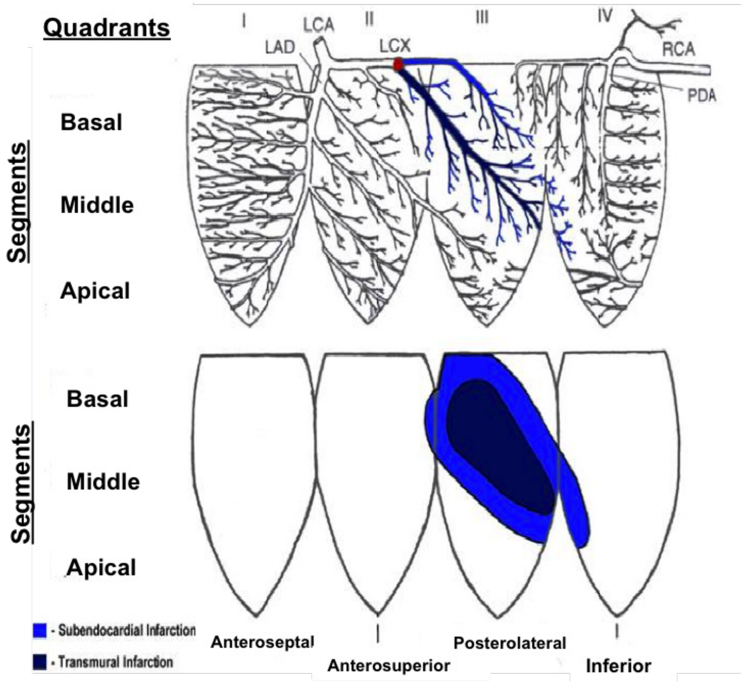
Left anterior descending coronary artery (LAD) occlusions producing the indicated myocardial infarctions.



MYOCARDIAL INFARCTION
MEDIUM POSTERIOR WALL MI (PMI)

The anterior wall (left, superior) and inferior wall (right, inferior) boundaries of the posterior wall of the left ventricle are represented in blue (below, left). The shaded area indicates the location of the infarction. The mercator projection (below,right) shows an occlusion of the left circumflex artery (LCX, red dot) which supplies the posterior wall via ***marginal*** branches. Infarction in the posterolateral quadrant of the mercator projection is depicted in the lower right.

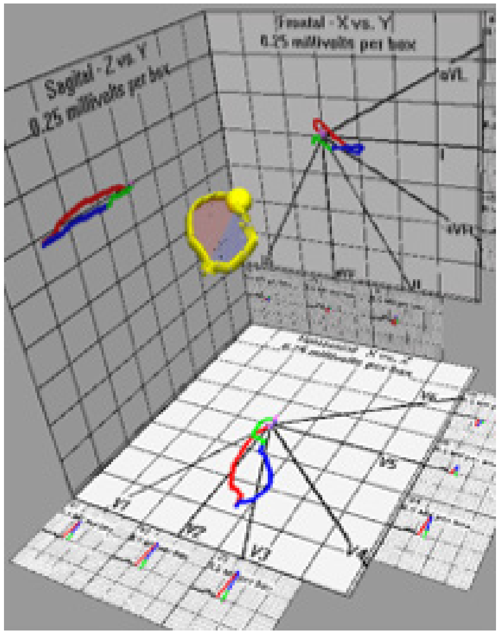




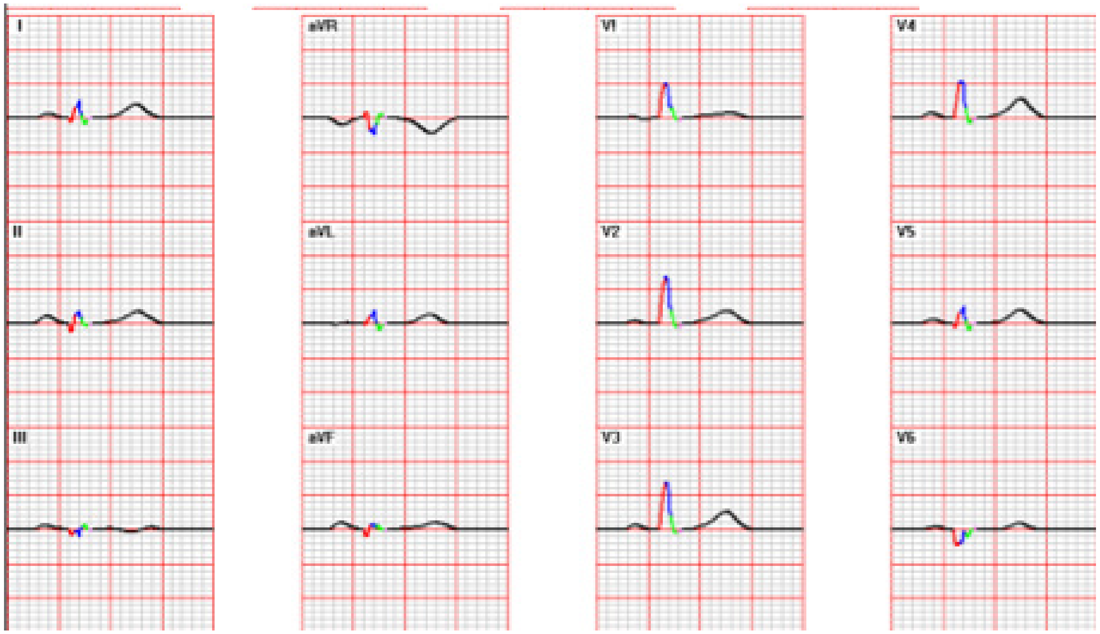
LARGE POSTERIOR WALL MI

A large posterior MI deflects the QRS sum vectors anteriorly and manifests as a anteriorly displaced 3D QRS vector loop. Similarly, the projection in the **horizontal** plane appears narrowed with marked anterior deviation (below left). The 12 lead ECG shows only R waves in leads V1 to V5 and a long duration Q wave in V6. The loss of posterior wall myocardial cells explains the absence of S waves in the precordial leads. The limb lead QRS complexes are small and irregular.

LARGE POSTERIOR WALL MI VCG



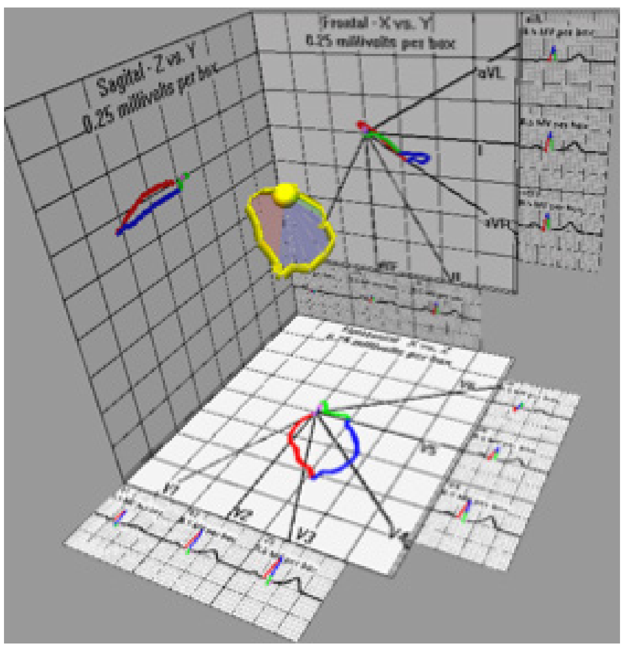
LARGE ANTERIOR WALL MI ECG



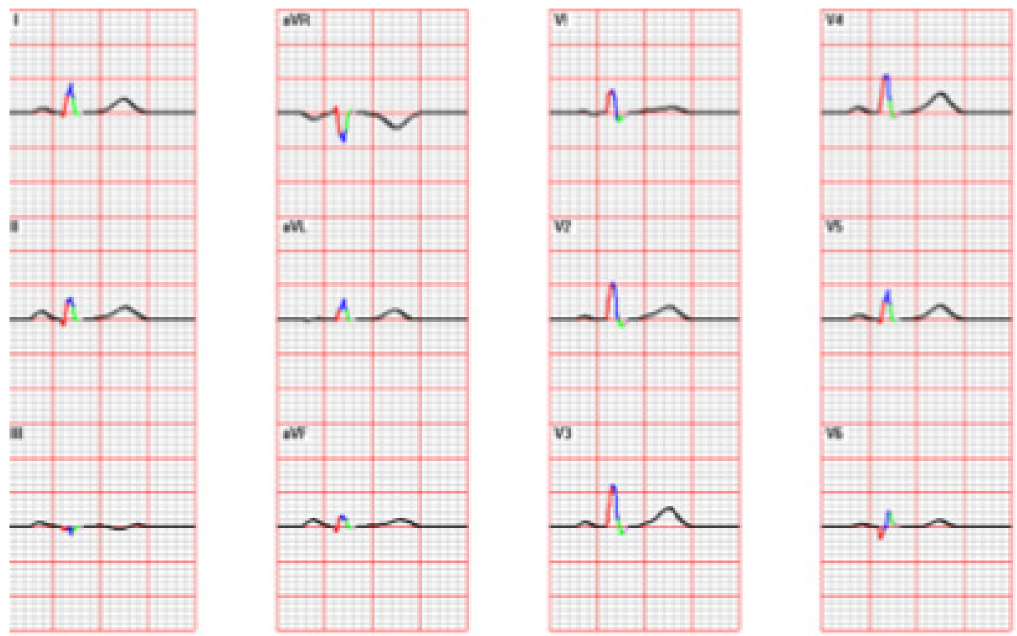
MEDIUM POSTERIOR WALL MI

As per the large posterior wall MI, a medium posterior wall MI rotates the 3D QRS loop anteriorly in the horizontal plane. Note that the 3D vector loop maintains a near normal planar orientation in the frontal plane (below left). This is also noted in the ECG by the lack of S waves in V1 – V3. V6 has a Q wave and a small R wave.

MEDIUM POSTERIOR WALL MI VCG



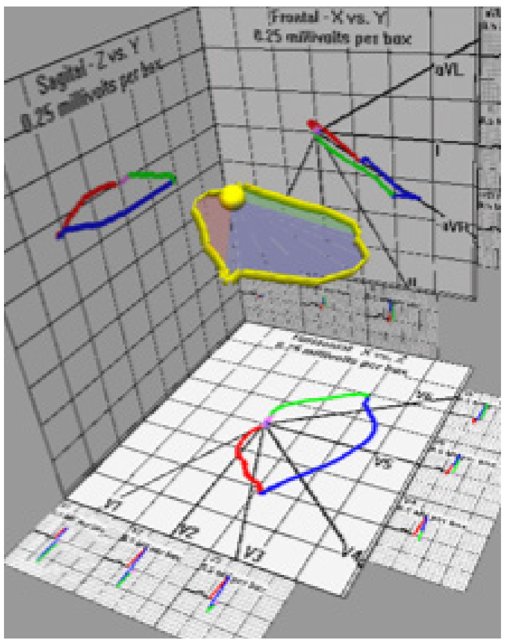
MEDIUM ANTERIOR WALL MI ECG



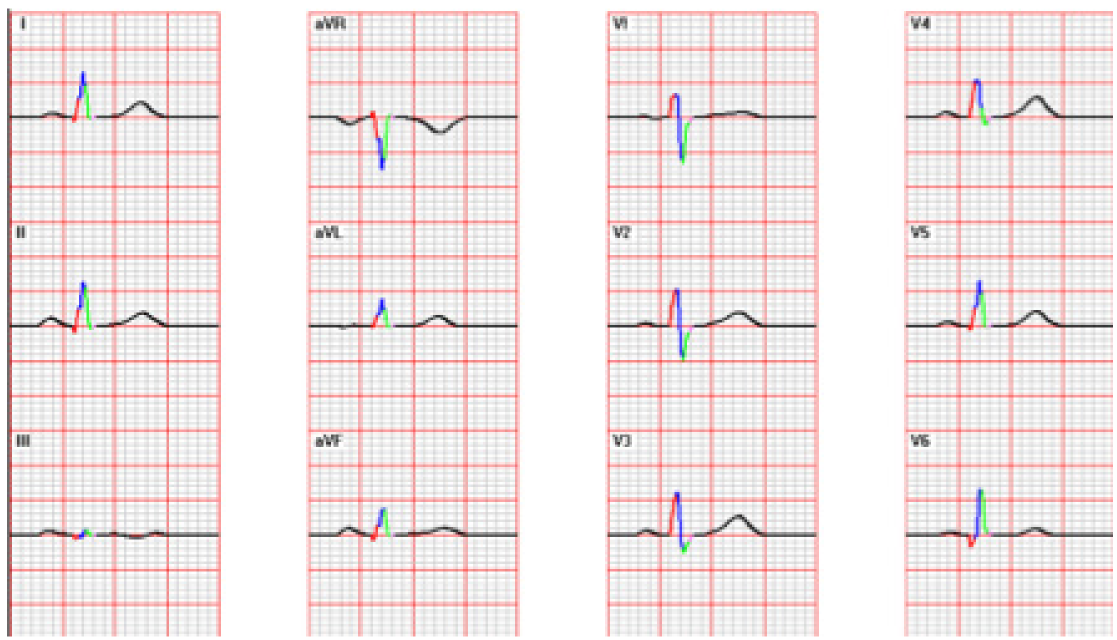
SMALL POSTERIOR WALL MI

A small posterior MI is probably the most difficult to distinguish from a normal heart. The 3D QRS vector loop is rotated anteriorly in the horizontal plane. A distinct R wave in V1, a R/S ratio >1 in leads V2 and V3 and a pathologic Q wave in lead V6 are suggestive of a small posterior MI.

SMALL POSTERIOR WALL MI VCG

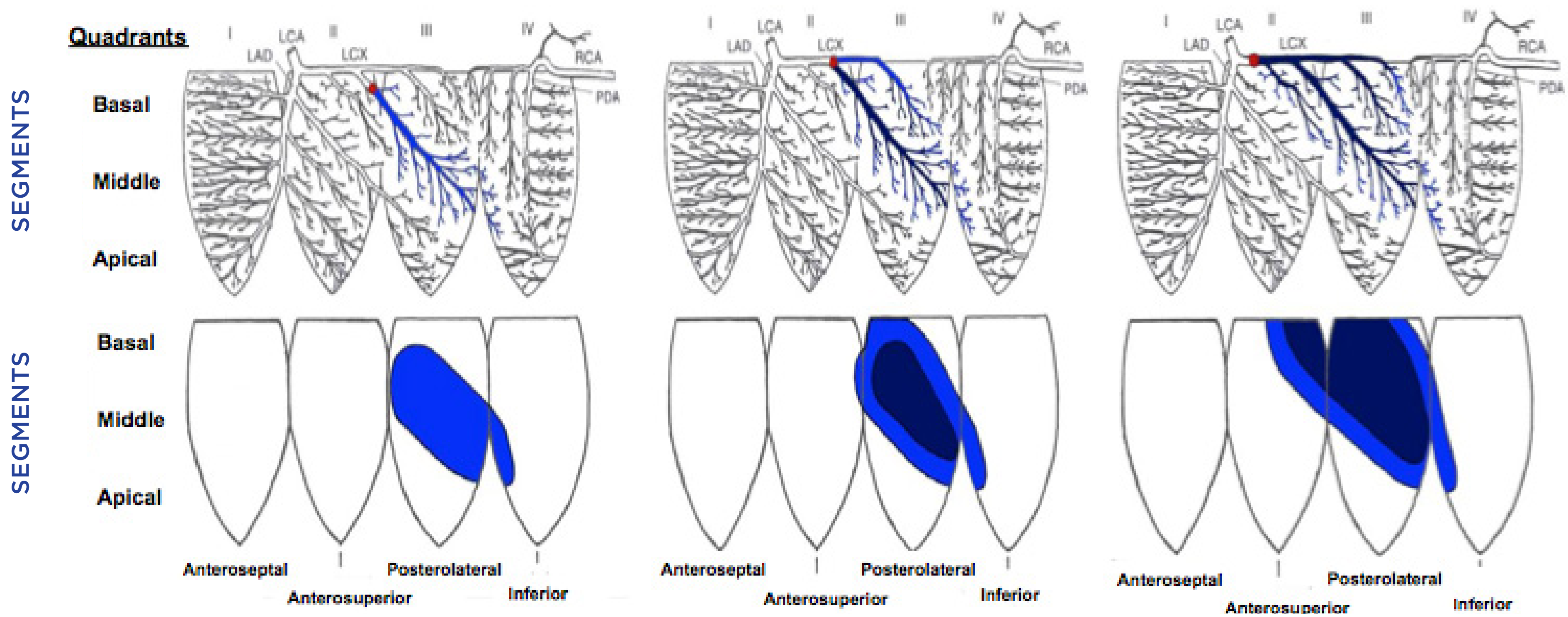


SMALL ANTERIOR WALL MI ECG



POSTERIOR WALL MI

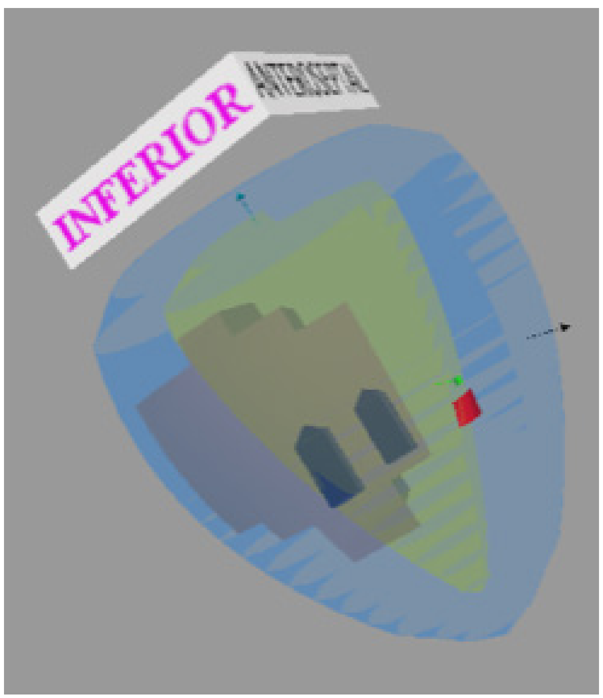
Left circumflex coronary artery (LCX) occlusions producing the indicated myocardial infarctions.

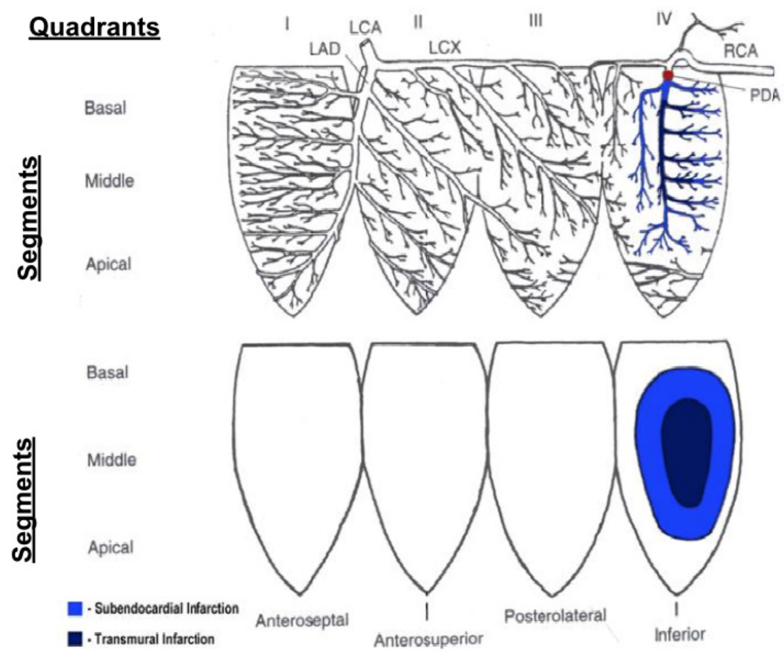


SMALL MEDIUM LARGE

MYOCARDIAL INFARCTION
MEDIUM INFERIOR WALL MI (IMI)

An inferior MI arises from an occlusion of the posterior descending coronary artery (PDA). The anterior wall (right, superior) and posterior wall (left, superior) boundaries of the inferior wall of the left ventricle are represented in blue (below, left). The shaded area indicates the location of the infarction. The mercator projection (below right) shows an occlusion of the posterior descending coronary artery (PDA, red dot) which supplies the inferior wall. Infarction in the inferior quadrant of the mercator projection is depicted in the lower right. Note that the apex is spared.

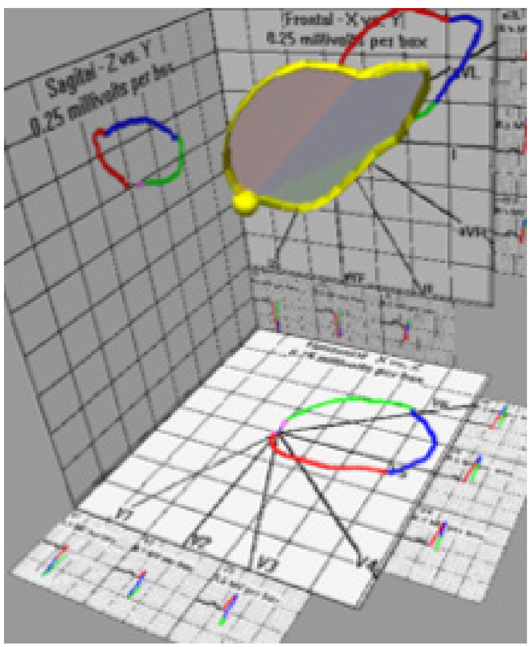




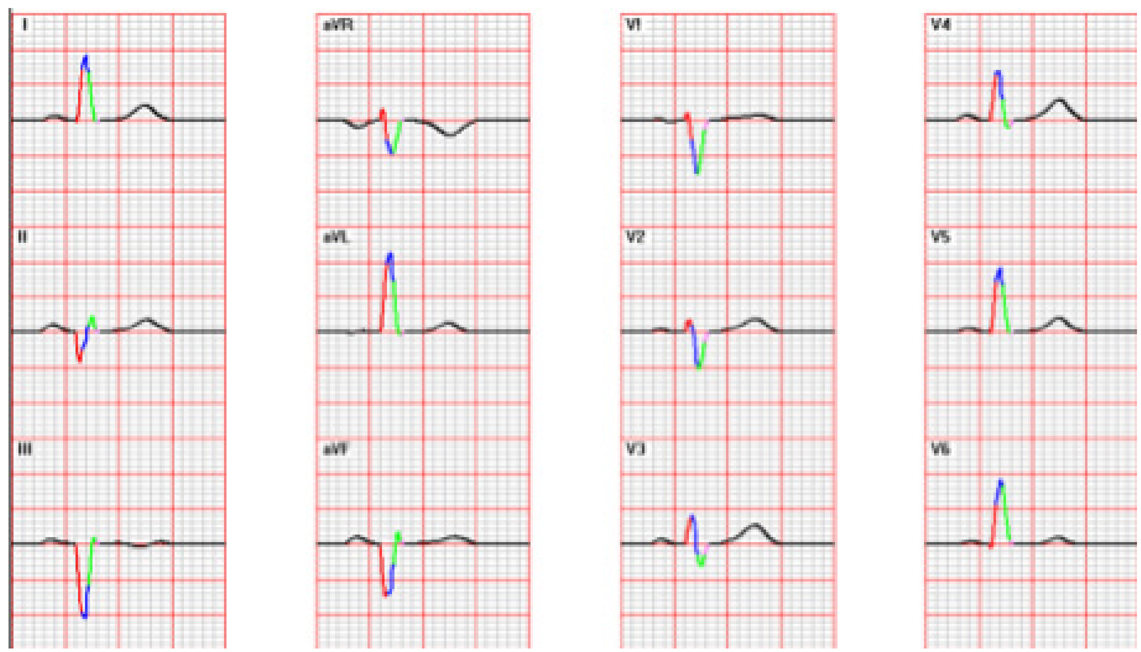
LARGE INFERIOR MI

A large inferior MI deflects the QRS sum vectors superiorly, elevating the 3D vector QRS loop . As a result, the corresponding projections in the sagittal and frontal planes showed marked superior deviation (below left). In the standard 12 lead ECG, deep prolonged Q waves appear in leads II, aVF and III with R < Q in all three leads. A prominent R wave is recorded in lead aVL.

LARGE INFERIOR WALL MI VCG



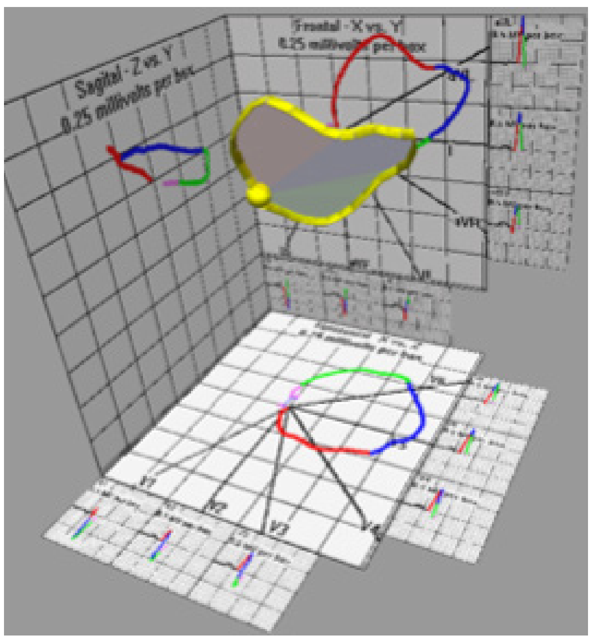
LARGE INFERIOR WALL MI ECG



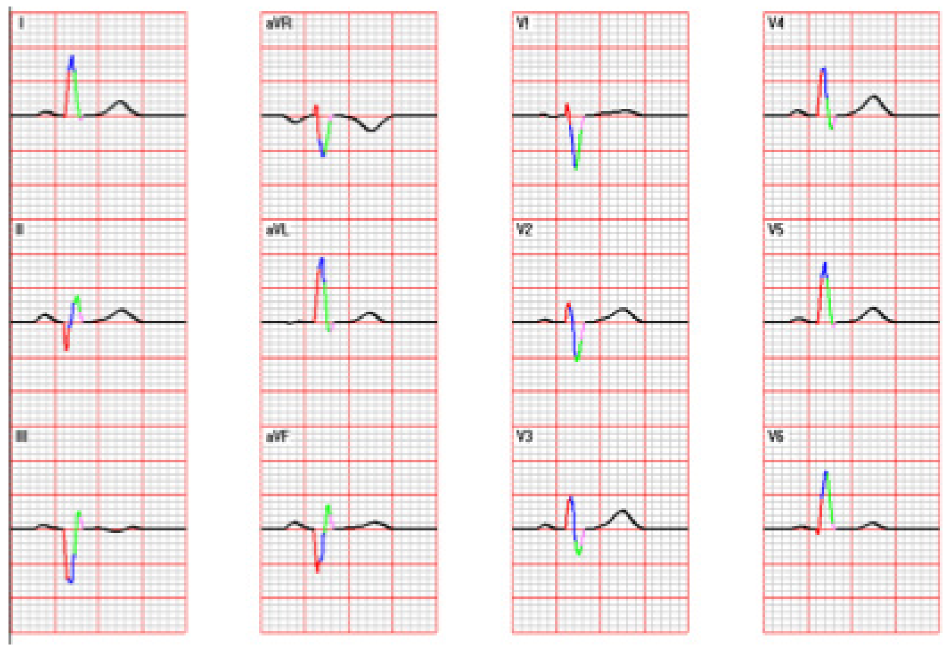
MEDIUM INFERIOR MI

In the case of medium inferior MI, the initial QRS sum vectors are deflected superiorly, elevating the leading (red) section of the 3D QRS vector loop. In the frontal plane projection, the initial segment arcs superiorly resulting in a clockwise rotation of projected sum vectors. As seen from the vector loop and superimposed standard ECG leads in the frontal plane (below left, rear), QR waves appear in leads II, aVF and III with R ≥ Q in lead II. Lead aVL remains strongly positive (below right).

MEDIUM INFERIOR WALL MI VCG



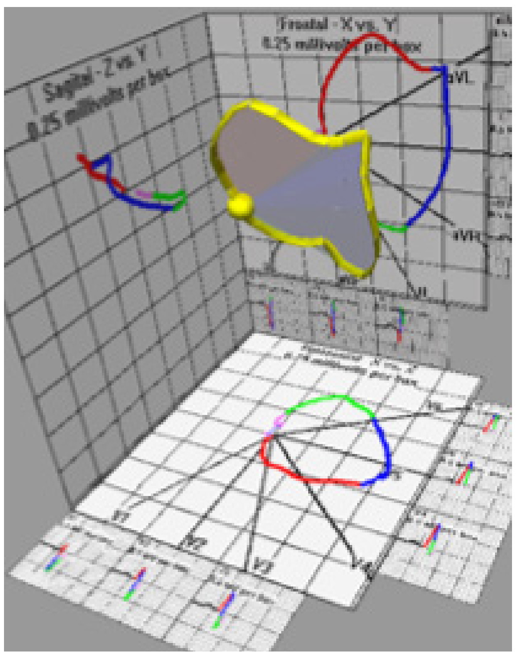
MEDIUM INFERIOR WALL MI ECG



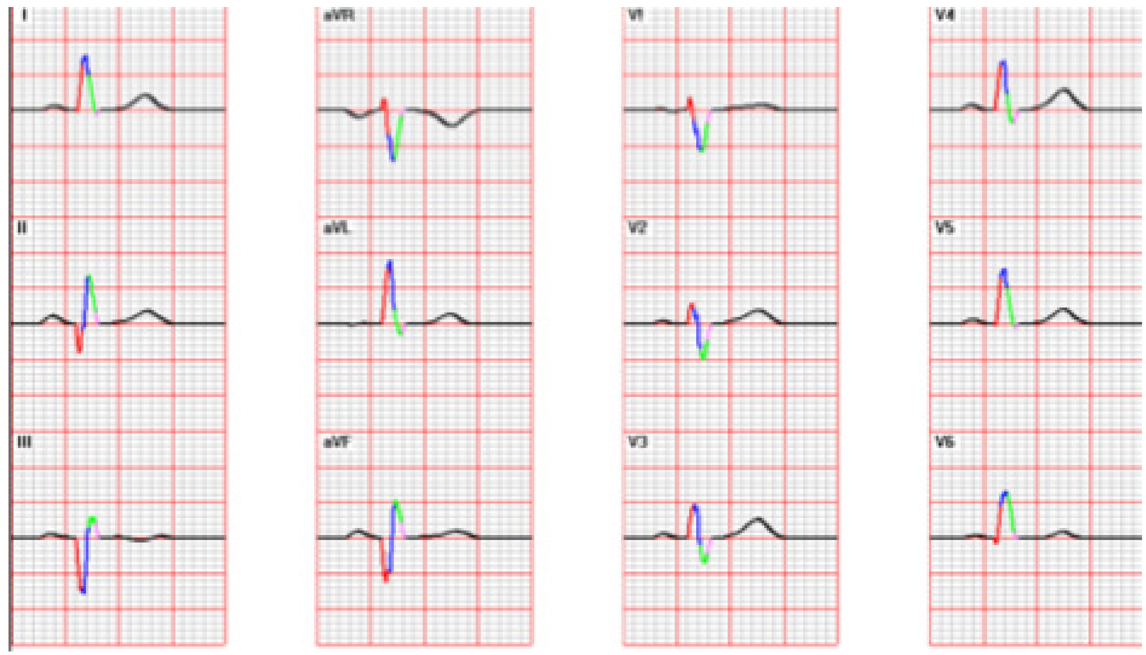
SMALL INFERIOR MI

In the case of small inferior MI, the initial vectors are again elevated, as seen in both the 3D vector QRS loop and in the frontal plane projection (red segment, below left). In addition, the plane of the vectors tilts into a slanted plane facing the back of the patient. The 3D vector loop planarity is clearly seen in the sagittal plane projection (below left). As before, QR waves appear in leads II, aVF and III but with R ≥ Q in lead aVF.

SMALL INFERIOR WALL MI VCG

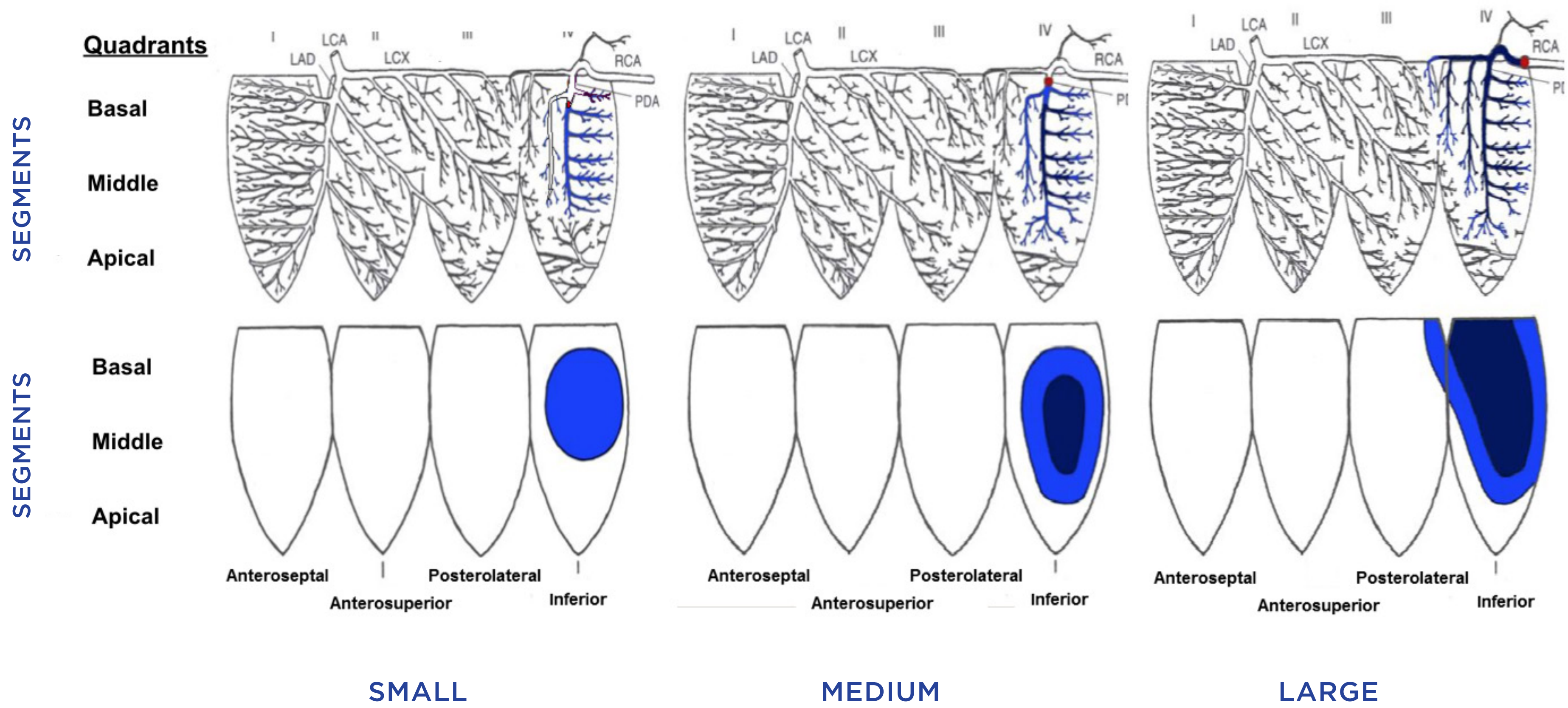


SMALL INFERIOR WALL MI VCG

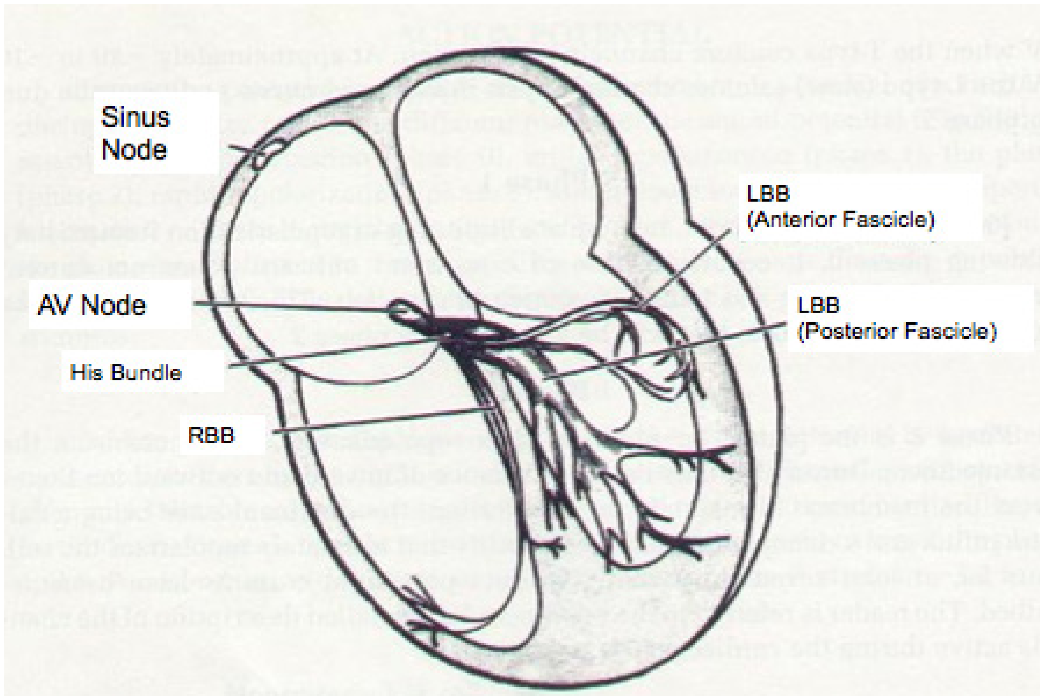


INFERIOR MI

Posterior descending coronary artery (PDA) occlusions producing the indicated myocardial infarctions.

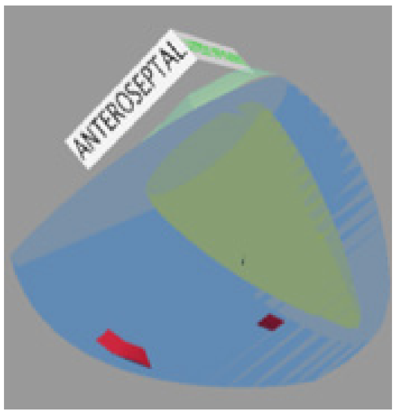


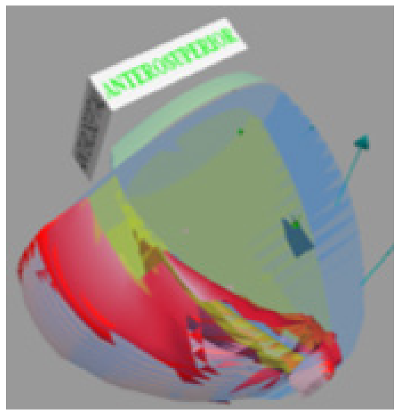
CONDUCTION DISTURBANCES
BUNDLE BRANCH BLOCKS

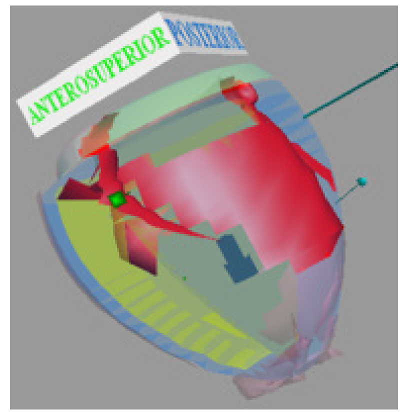


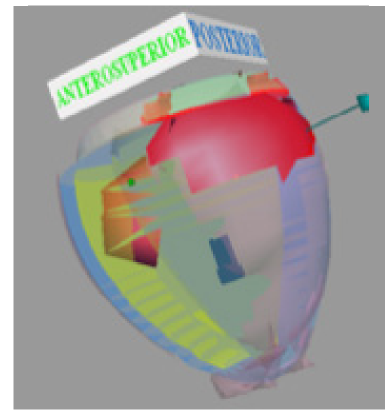
A description of the electrical activation of the heart was presented in page 11. The bundle branch blocks occur at the origins of the left or right bundle branches immediately after the bundle of His segment. Asynchronous activation of the ventricles prolongs and distorts the 3D vector loop and standard ECG QRS complex.

LEFT BUNDLE BRANCH BLOCK (LBBB)









10 MSEC

Since the LBB is blocked, activation begins solely in the right ventricle.

40 MSEC

As the activation of the RV nears completion, impulses conducted from the RV begin to activate the LV.

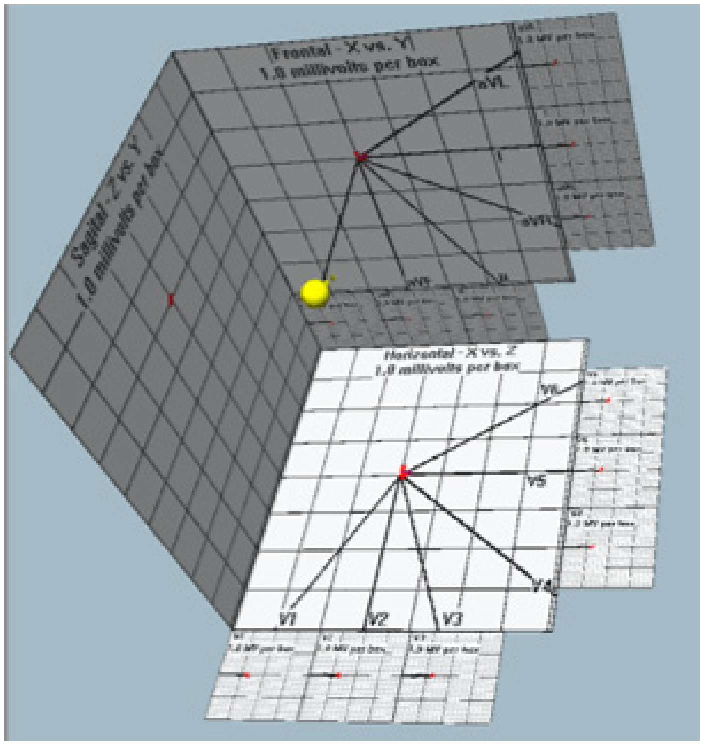
100 MSEC

The left ventricle nears full activation and the posterior vector is maximum.

125 MSEC

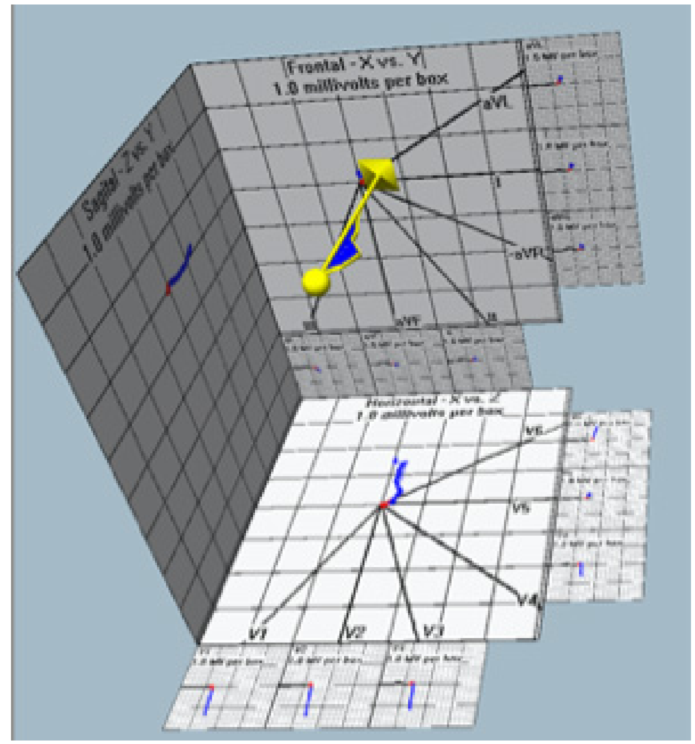
The activation of the left ventricle ends in the basal posterior quadrant.

LBBB LOOPS



25 MSEC

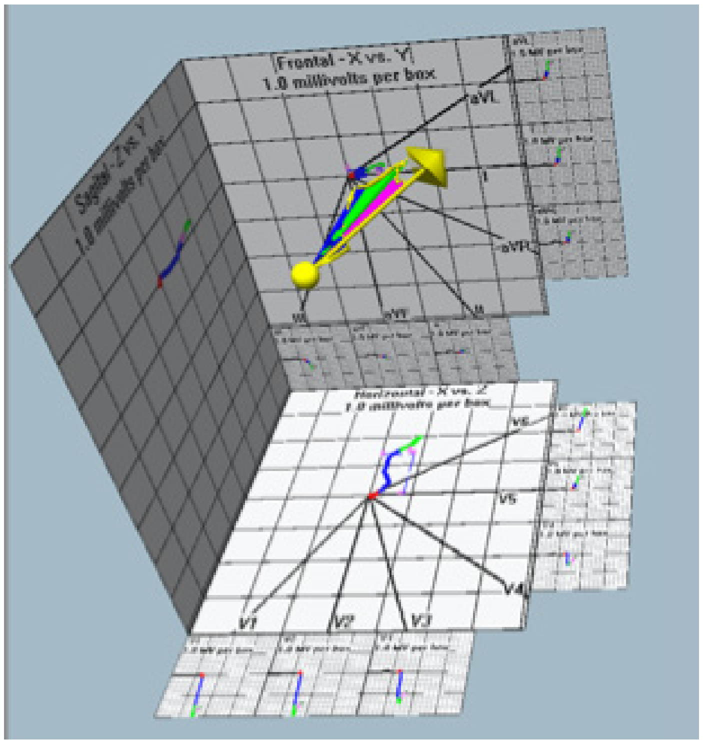
Small vector directed posteriorly in horizontal plane reflecting RV septal activation (red segment).

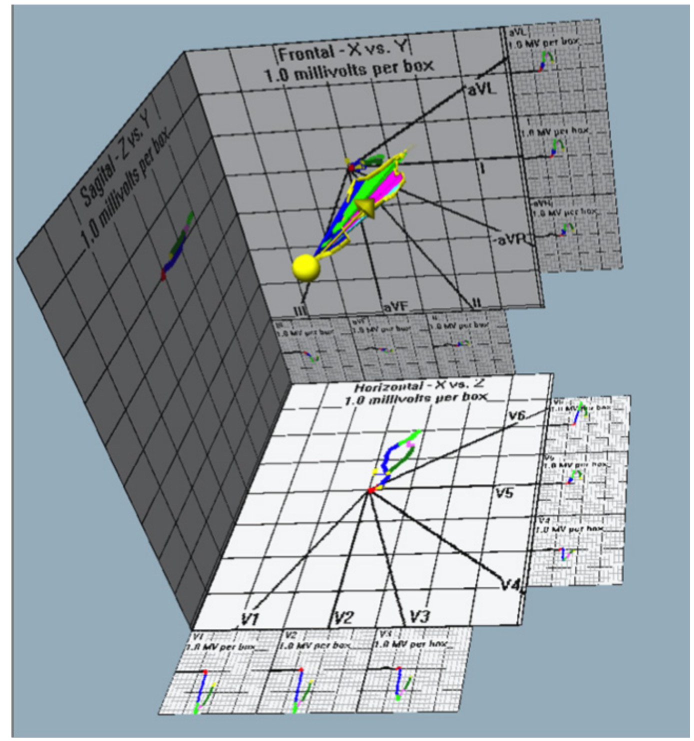


50 MSEC

Increased size posterior vector reflecting combined RV and LV septal activation (blue segment).

LBBB LOOPS





100 MSEC

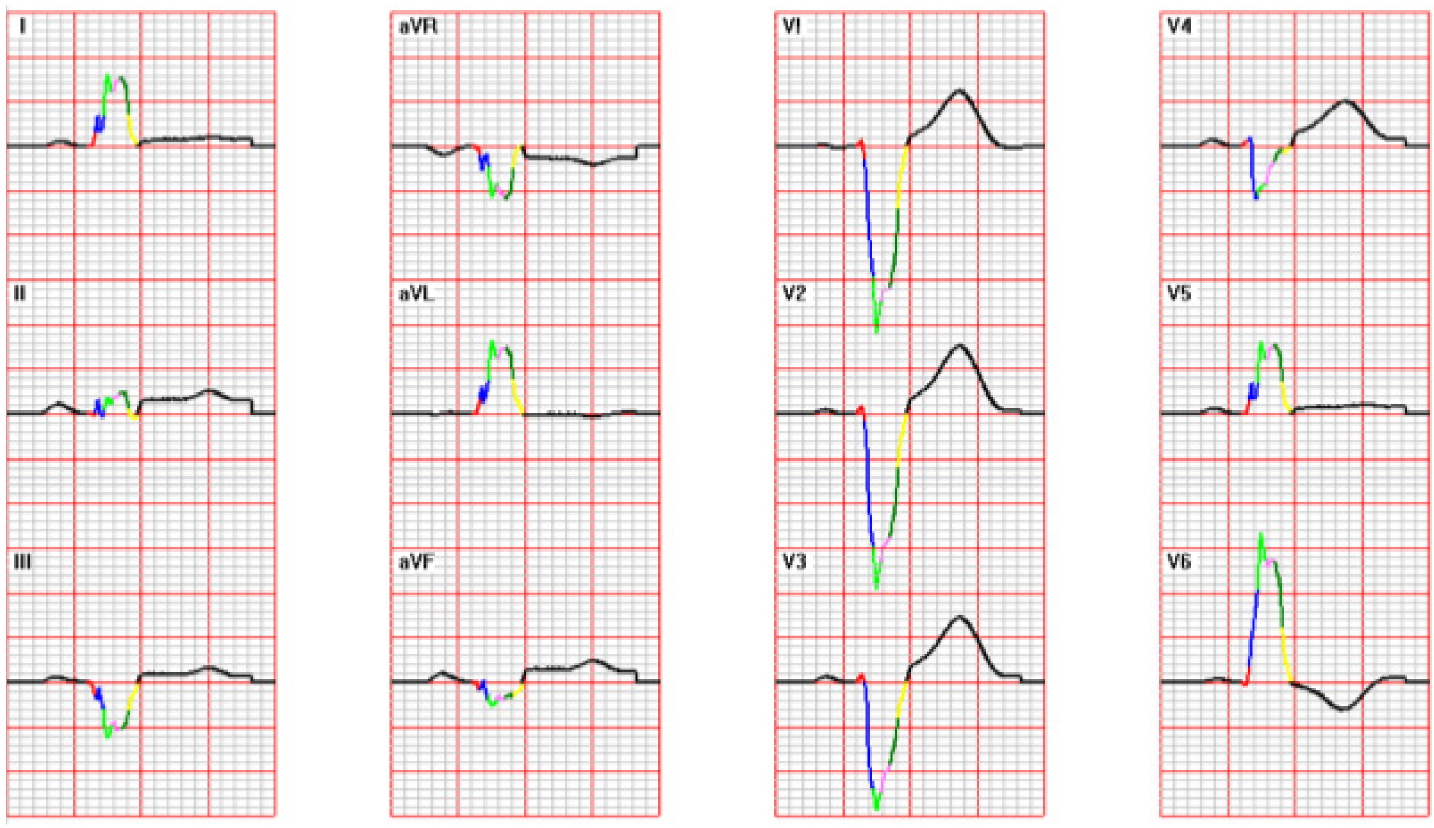
Large posterior vector produced by anterior to posterior activation of the LV walls and the posterior quadrant (green and pink segments).

140 MSEC

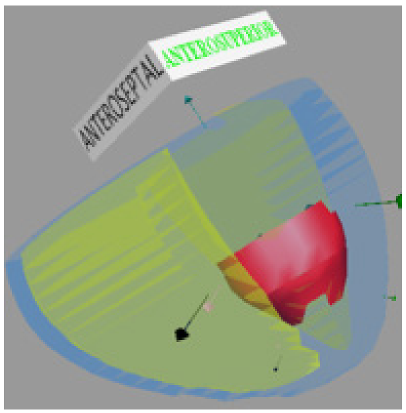
Final activation at the base of the posterior quadrant still in the posterior direction. The returning dark green segment of the vector loop crosses over the initial blue segment.

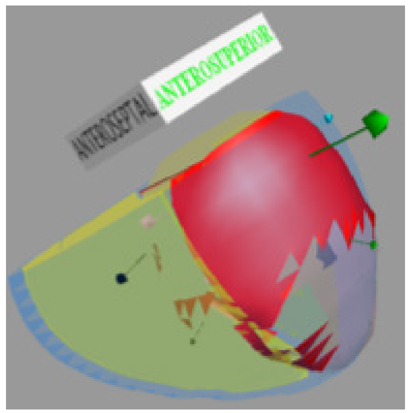
LBBB 12 LEAD ECG

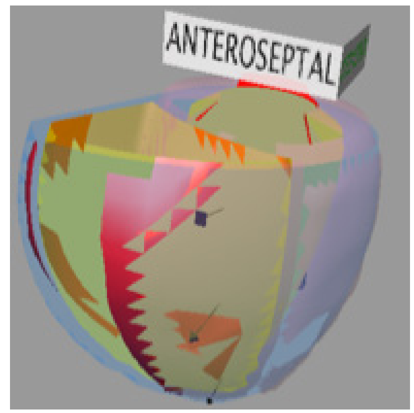
The QRS duration is longer than 120msec with prominent Q waves in leads V1, V2 and V3. In the frontal plane, the maximum vector lies near -15 degrees, between leads I and aVL.

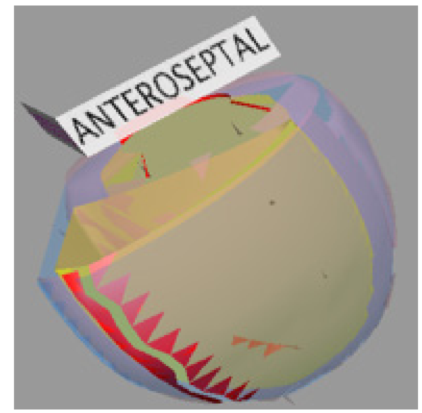


RIGHT BUNDLE BRANCH BLOCK (RBBB)









10 MSEC

Since the RBB is blocked, Initial activation occurs solely in the left ventricle.

50 MSEC

The activation wavefront spreads through the left ventricle. The initial vectors are near normal.

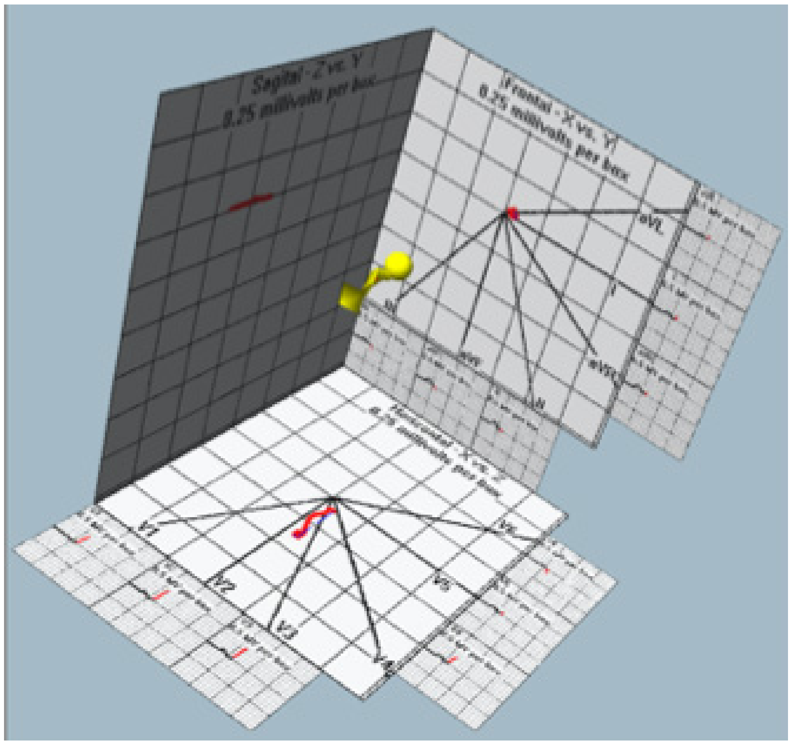
100 MSEC

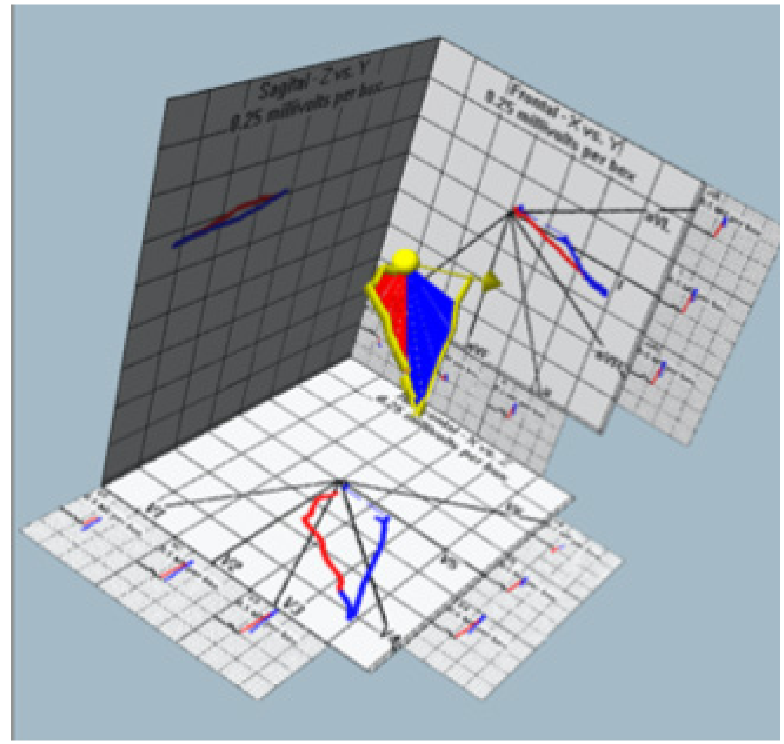
The right ventricle is activated by spread from the left side. The sum vector is directed anteriorly and rightward.

125 MSEC

Activation nears completion at the right border of the RV.

RBBB LOOPS





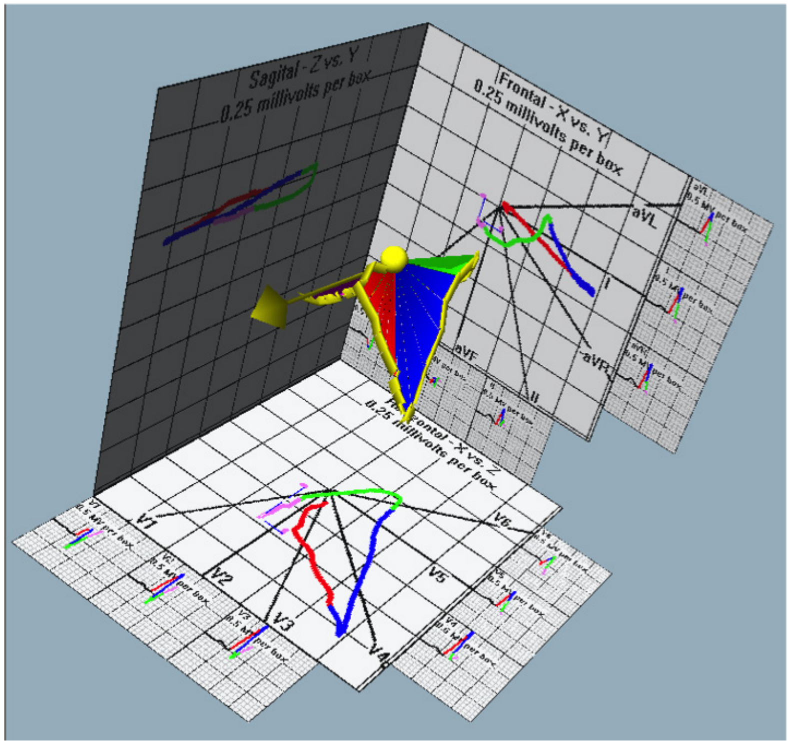
10 MSEC

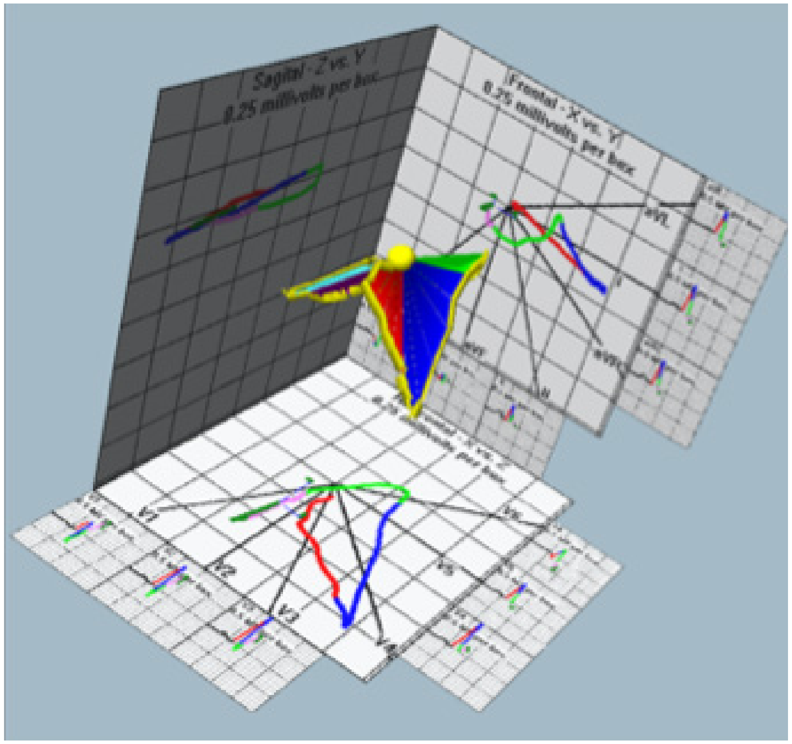
The initial vectors are anterior, as seen in the normal heart (red segment).

50 MSEC

Increased size posterior vector reflecting combined RV and LV septal activation (blue segment).

RBBB LOOPS





100 MSEC

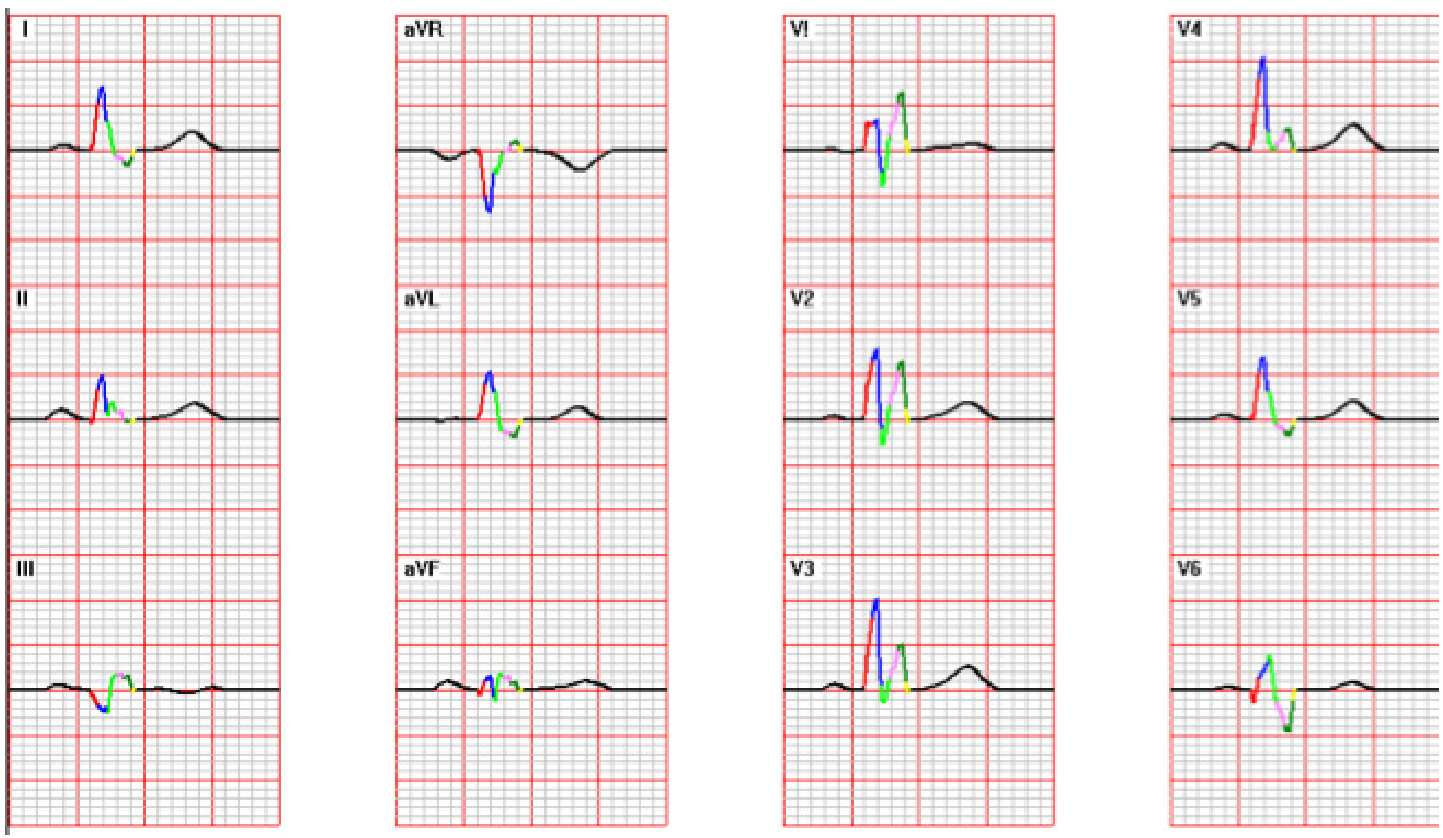
As LV activation ends, RV activation dominates, producing "new" rightward, anterior vectors in the horizontal plane (pink segment).

125 MSEC

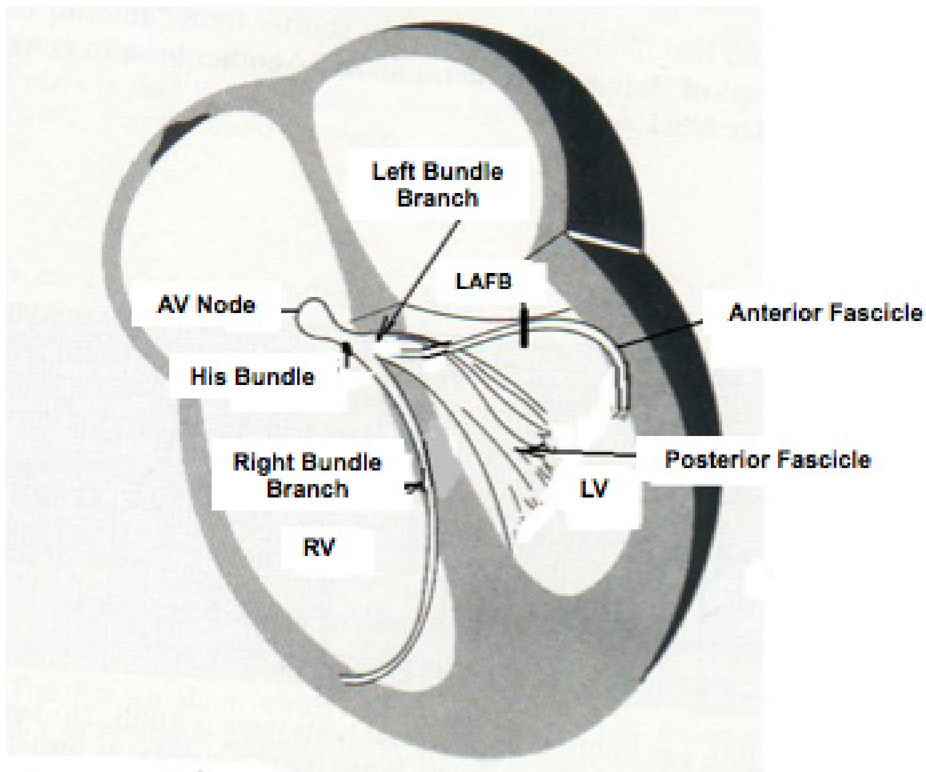
RV activation ends and a second peak emerges anteriorly in the horizontal plane, typical of RBBB (pink and dark green segments).

RBBB 12 LEAD ECG

A biphasic QRS appears in leads V1, V2 and V3 and the
the QRS duration exceeds 110 msec.

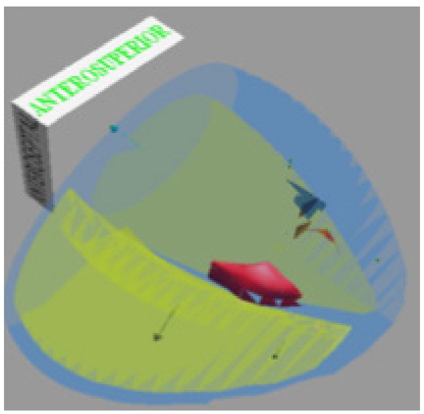


LEFT ANTERIOR FASCICULAR BLOCK



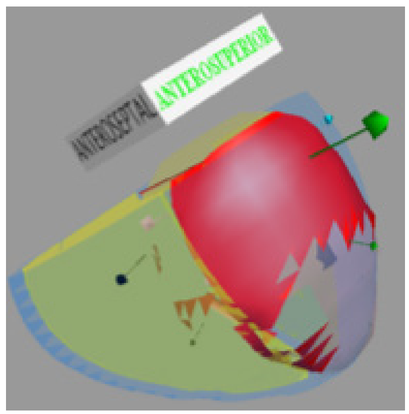
Left Anterior Fascicular Block (LAFB) is indicated by the black hash transecting the fascicle.

LEFT ANTERIOR FASCICULAR BLOCK (LAFB)



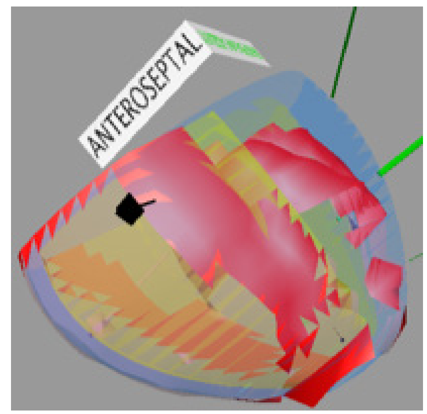
10 MSEC

The initial activation is restricted to the inferior side of the septum.



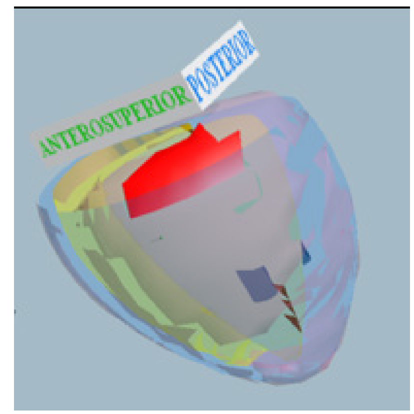
50 MSEC

Activation spreads to the posterior and anterosuperior quadrants of the left ventricle



75 MSEC

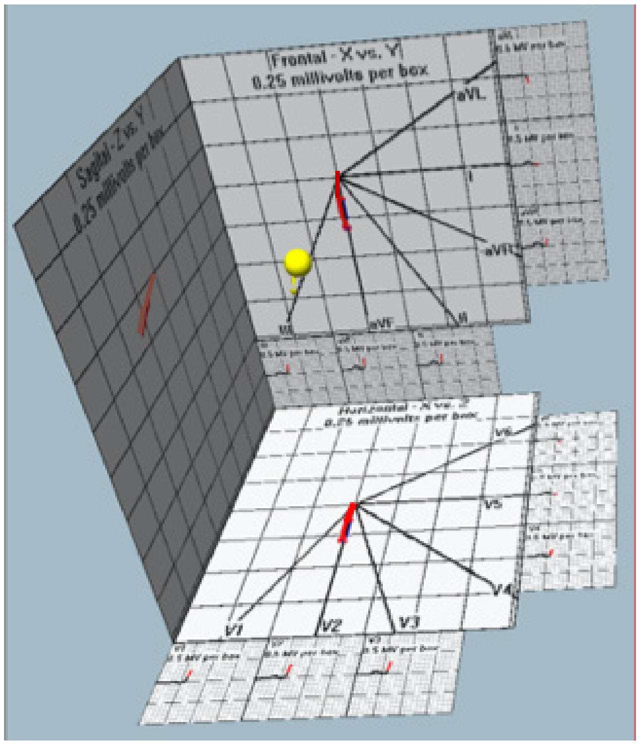
The basal segments of the anterosuperior and postereior quadrants are dominant.



100 MSEC

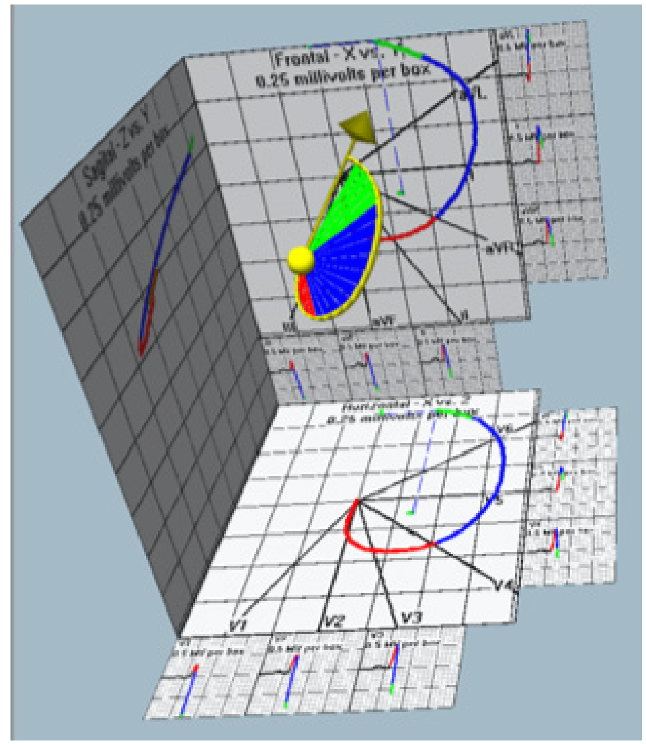
The LV activation sequence terminates at the base in the anterosuperior and posterior quadrants.

LAFB



10 MSEC

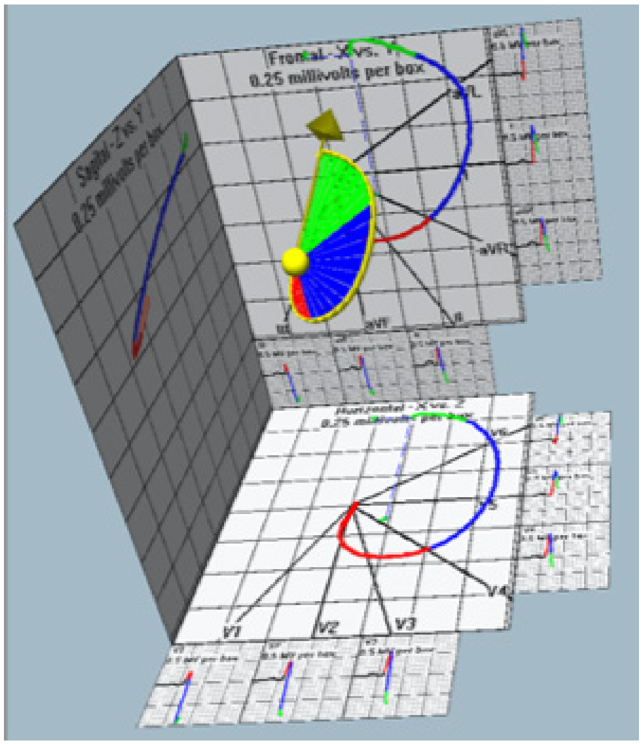
The initial activation is anterior as shown by the red segment in the horizontal plane.



50 MSEC

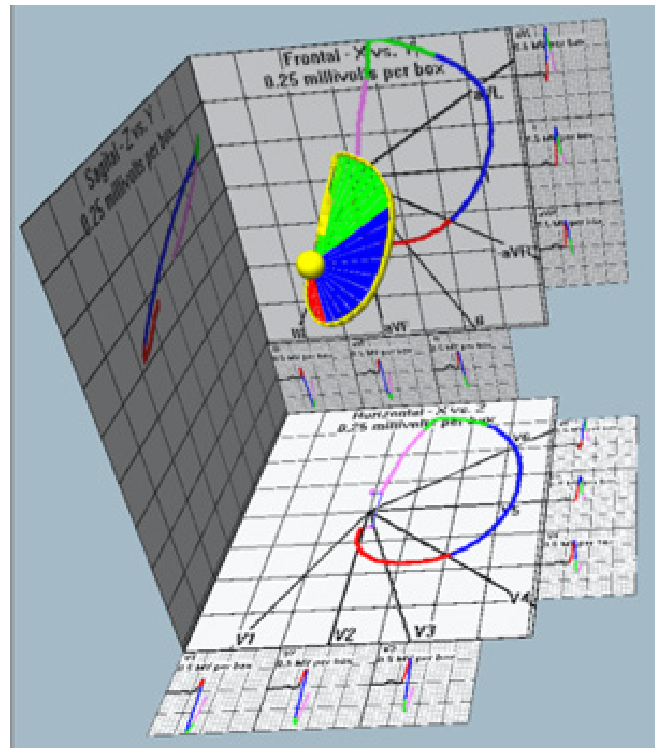
At 50 msec, the sum vector points posteriorly (horizontal plane) and superiorly (frontal plane). Note that the QRS sum vectors form a plane in three dimensions.

LAFB



75 MSEC

The vector continues posteriorly in the horiztonal plane.

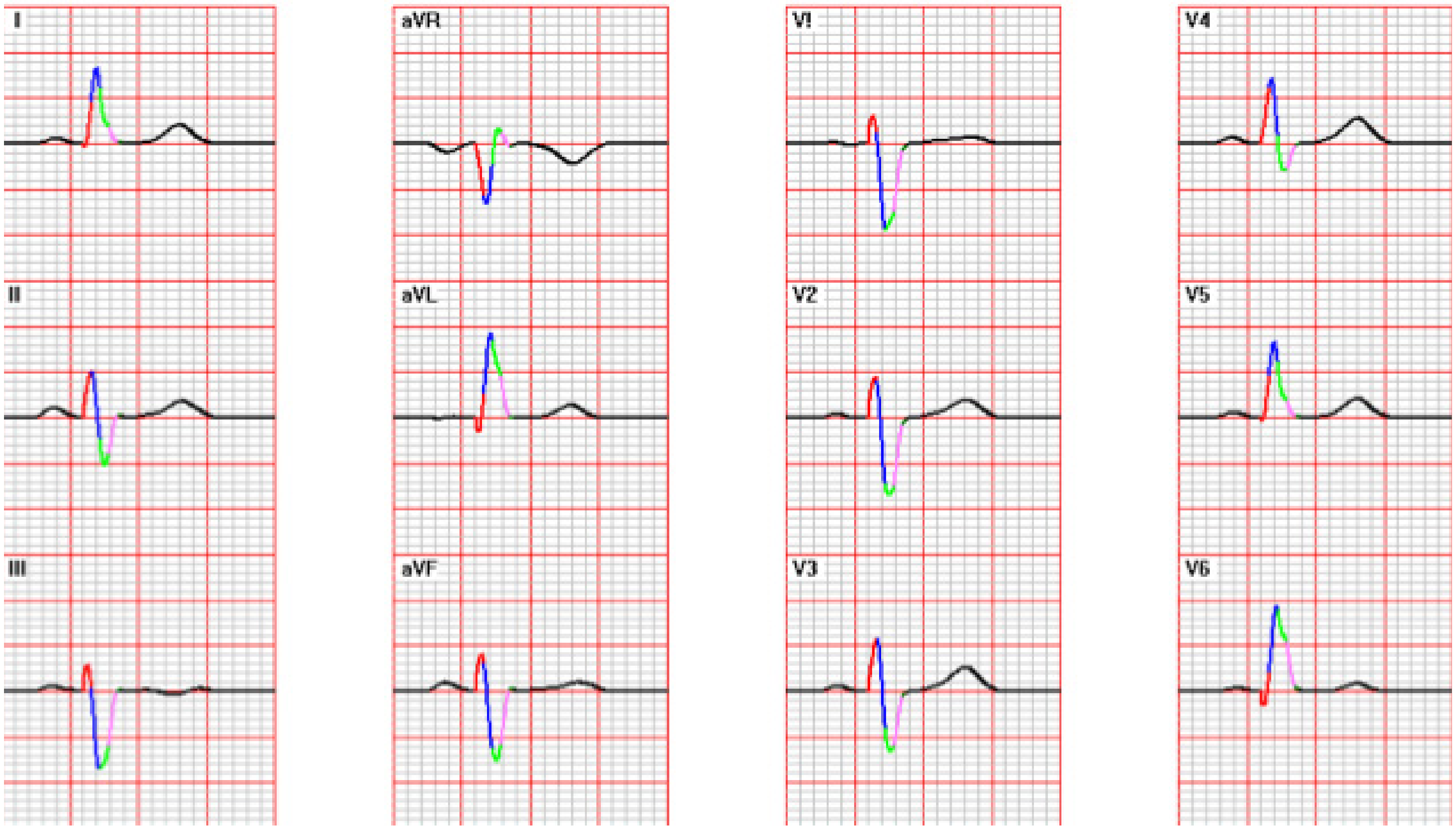


100 MSEC

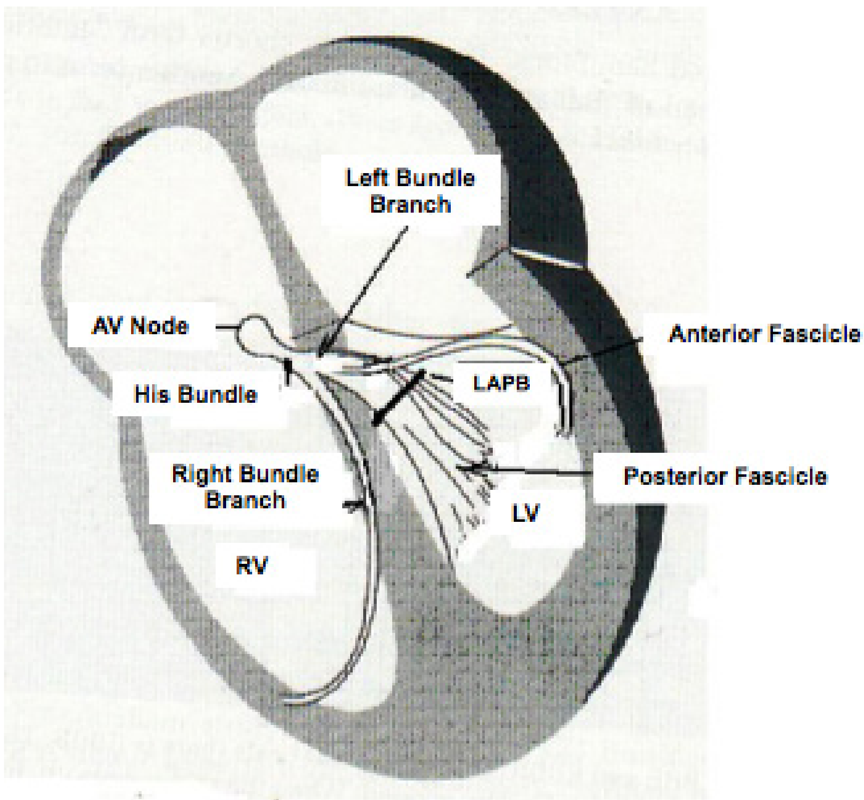
The final vectors retreat to zero, completing a planar 3D loop. Note the near linearity of the sagittal plane projection.

LAFB ECG

The LAFB ECG is notable for large S waves in leads II, aVF and III. The QRS angle in the frontal plane is shifted to between -30 and -60 degrees and the QRS interval may be either normal or increased up to 110 ms.

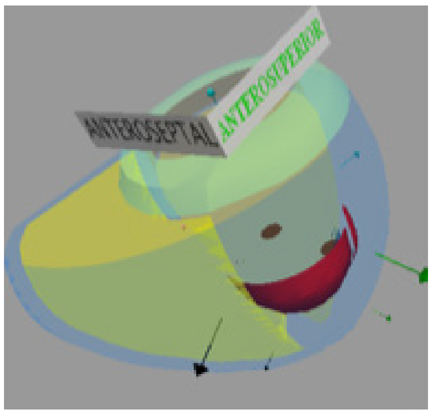


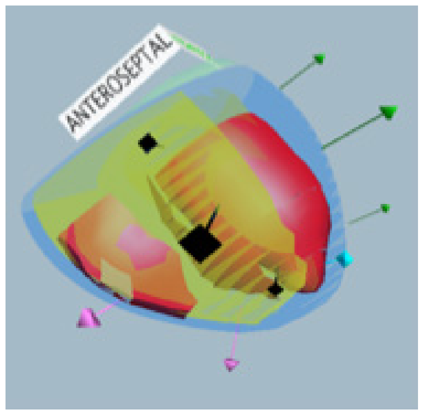
LEFT POSTERIOR FASCICLE BLOCK

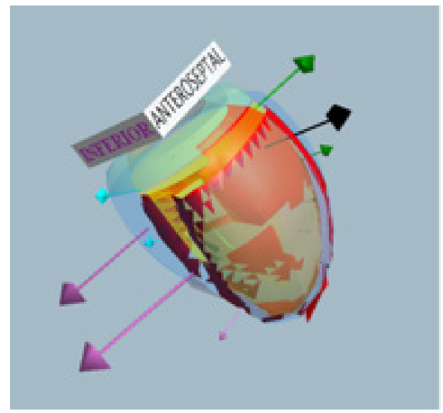


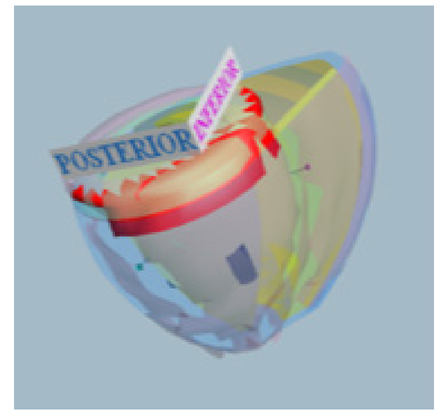
The Left Posterior Fascicular Block (LPFB) is indicated by the black hash transecting the fascicle.

LEFT POSTERIOR FASCICULAR BLOCK (LPFB)









10 MSEC

The initial activation of the LV extends from the anterior papillary muscle midway to the posterior papillary muscle. Thus, only anteroseptal and anterosuperior vectors are initially generated.

25 MSEC

Rapidly developing inferior vectors cancel the anterosuperior vectors. In addition, posterior vectors are smaller than the anterior vectors.

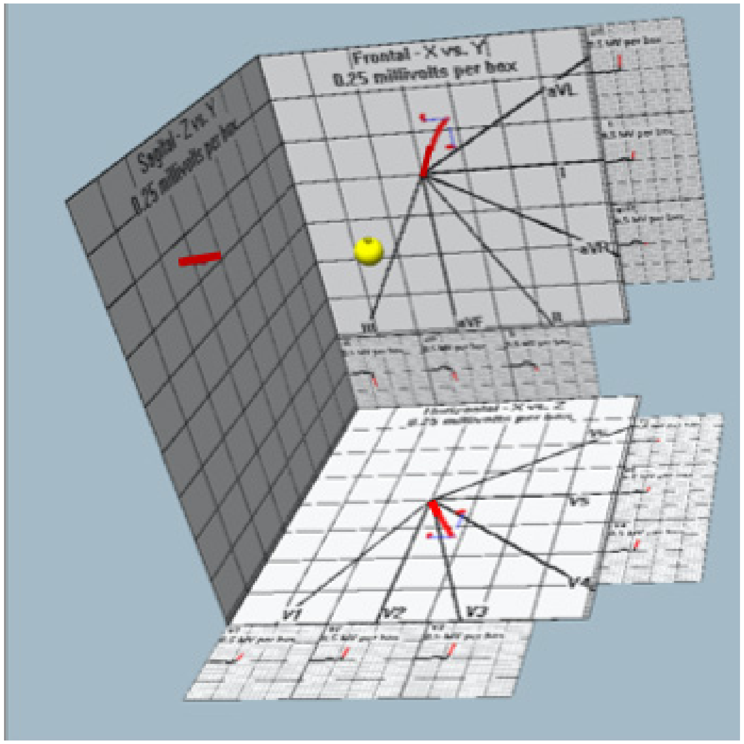
50 MSEC

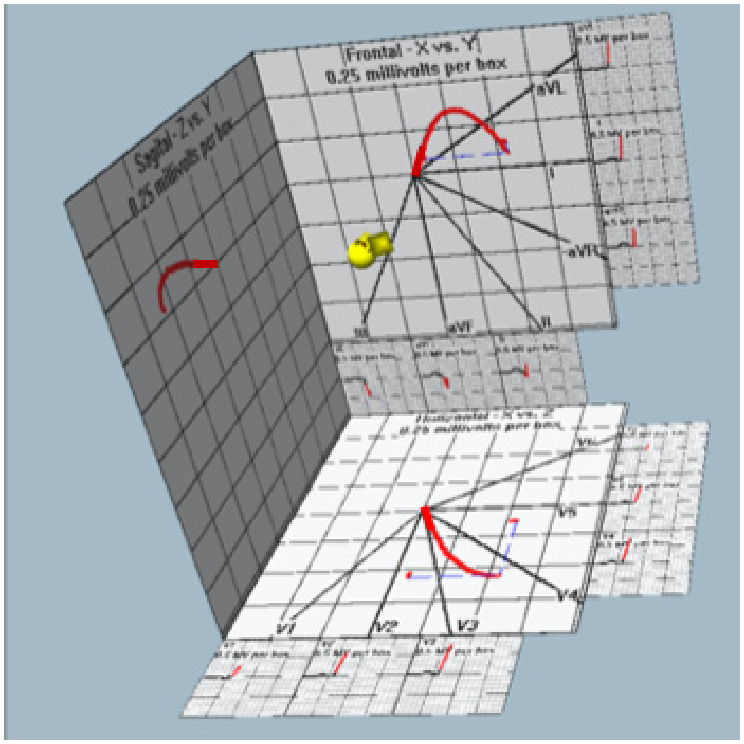
Inferior vectors dominate and the sum vector points inferiorly in the frontal plane. Posterior vectors now cancel the anterior vectors.

90 MSEC

The LV activation sequence terminates at the base in the posterior and inferior quadrants.

LPFB VECTOR LOOPS





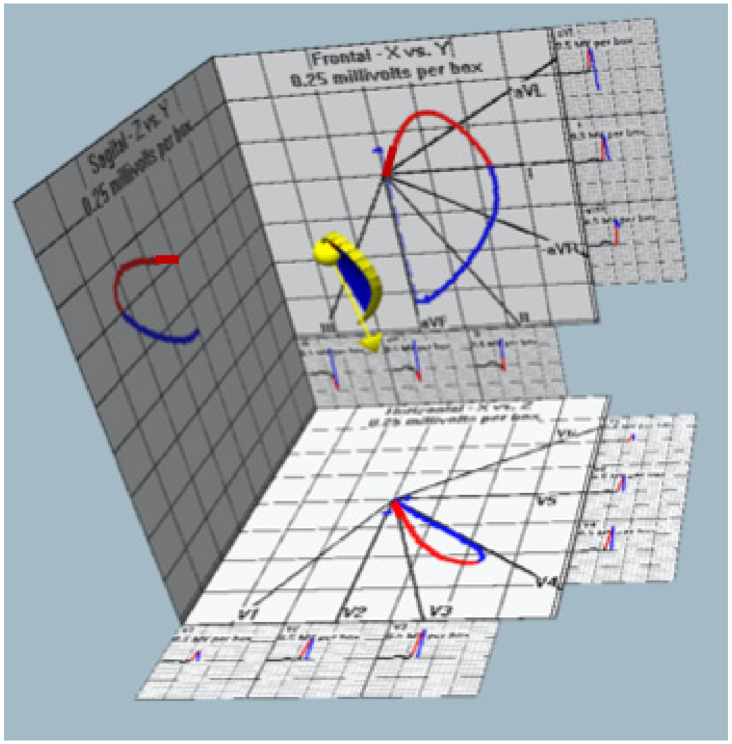
10 MSEC

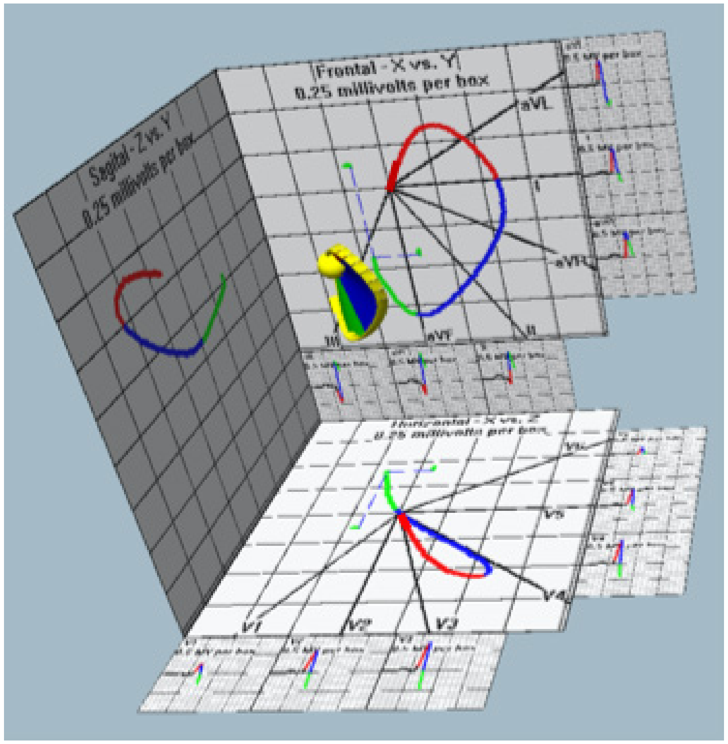
The initial vectors point superiorly, anteriorly and leftward, as expected from the initial activation described previously.

25 MSEC

As the inferior quadrant activates, the vector loop begins to swing posteriorly in the horizontal plane

LPFB VECTOR LOOPS





50 MSEC

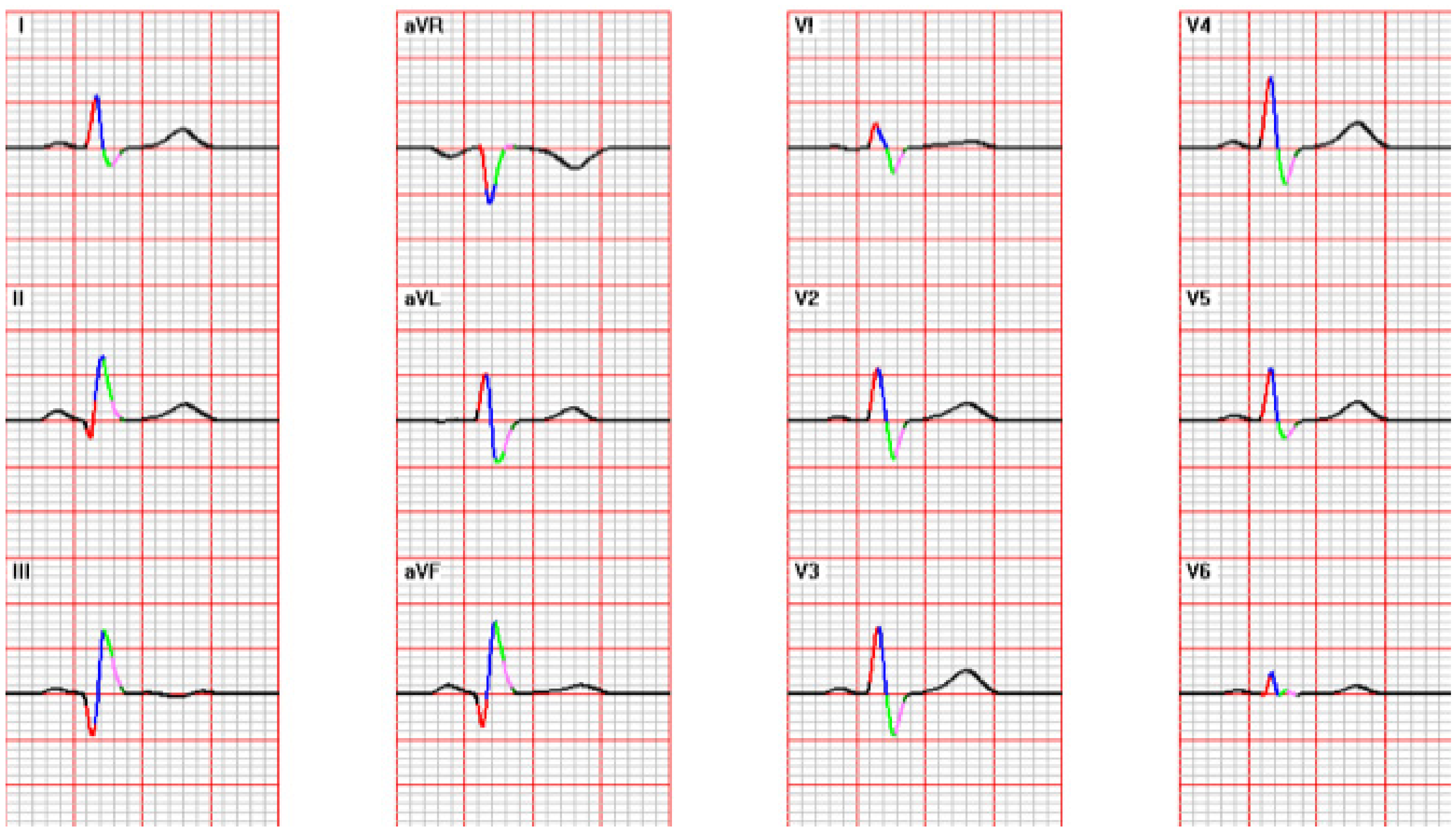
At 50 msec, the maximum deflection lies in the inferior direction at an angle of 90 degrees in the frontal plane, a characteristic of LPFB.

75 MSEC

The final vectors return to zero from inferior (frontal plane) and posterior and rightward (horizontal plane) locations. Note that the plane of the vectors is near vertical.

LPFB ECG

The presence of Q waves followed by large R waves in leads II, aVF and III and a QRS angle greater than 90 degrees in the frontal plane is characteristic of LPFB. The S waves present in leads I and V3 and V4 reflect the posterior location of the final vectors in the frontal and horizontal planes, respectively.



THANK YOU