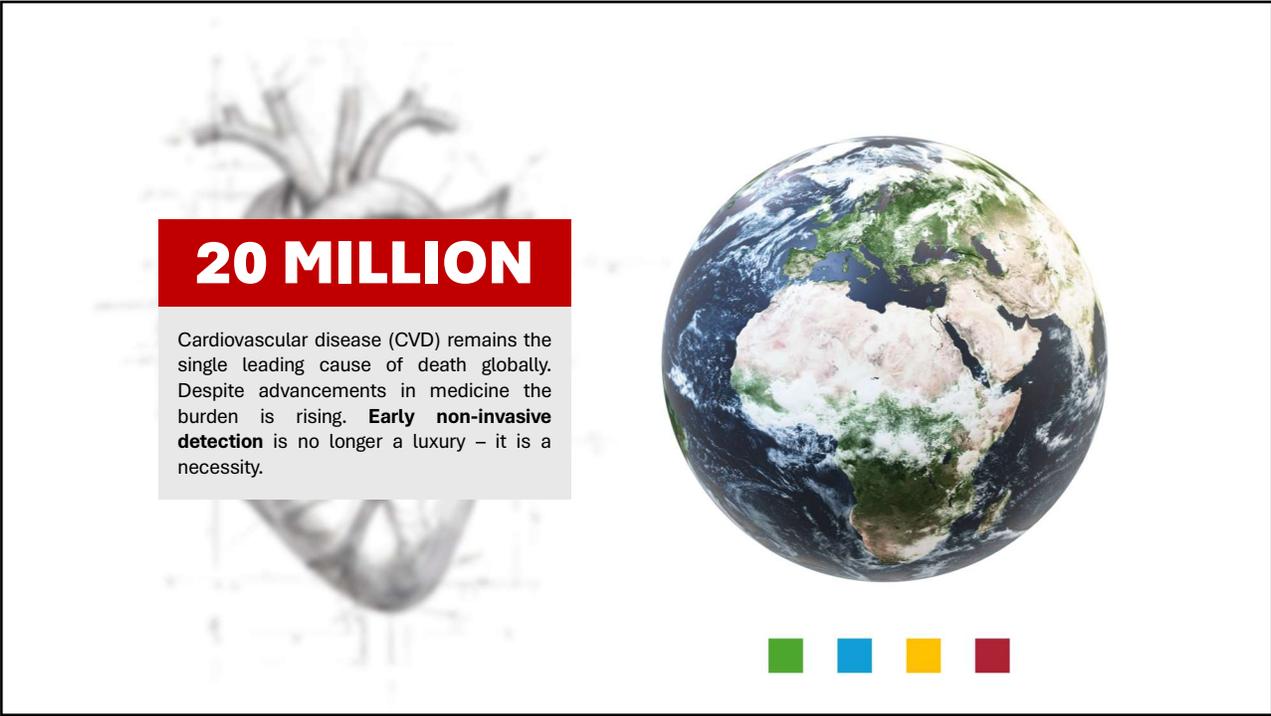


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2

20 MILLION

Cardiovascular disease (CVD) remains the single leading cause of death globally. Despite advancements in medicine the burden is rising. **Early non-invasive detection** is no longer a luxury – it is a necessity.

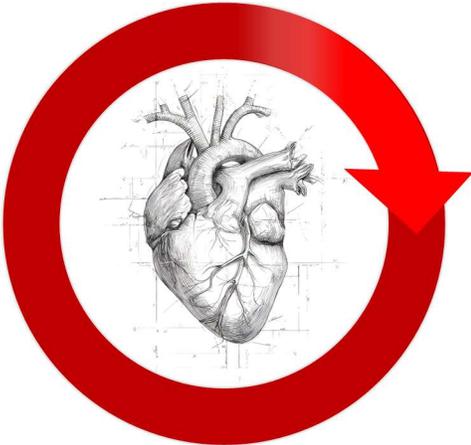
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For many years, the diagnostic tools available were either **very limited, expensive** or associates with **high risk**.

- Regular ECG / Stress ECG
- Echocardiogram
- Coronary Angiography



3



CARDIAC CT

Cardiac CT (CCTA) is now the preferred first-line tool for suspected Coronary Artery Disease (CAD).

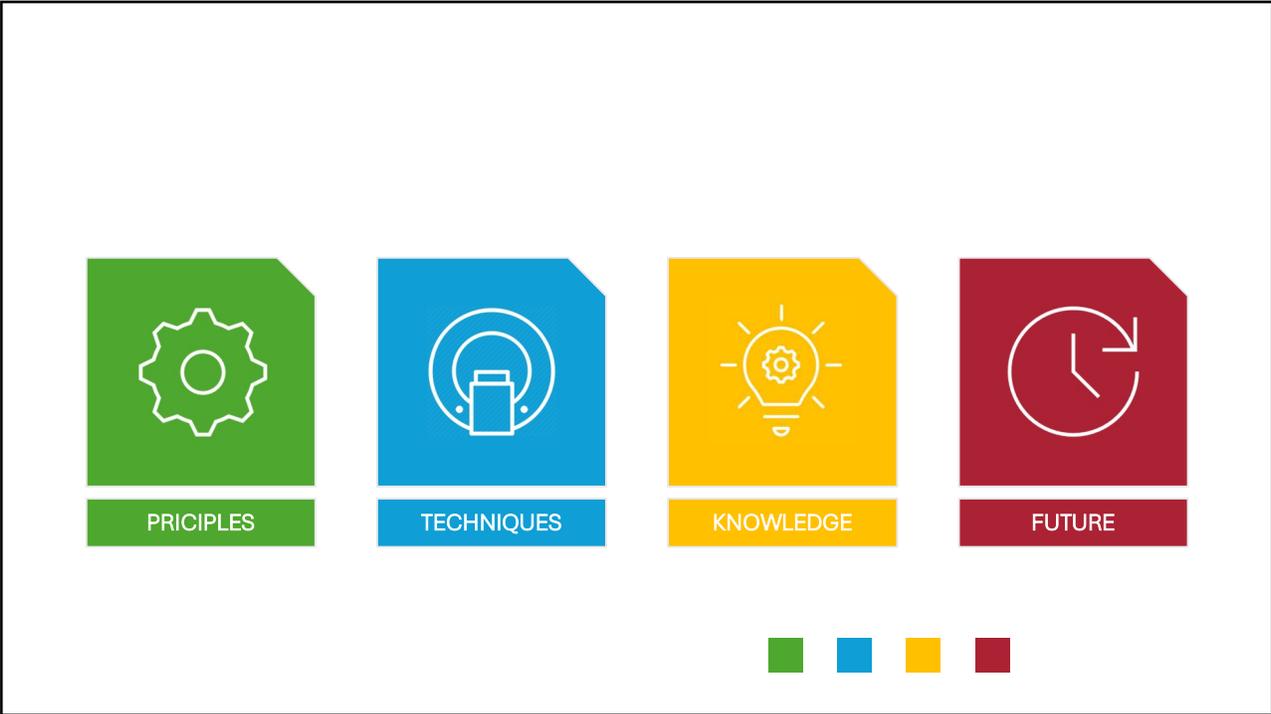
- high accuracy
- excellent negative predictive value
- non-invasive nature
- cost-effectiveness

especially for **low-to-intermediate risk chest pain**, as endorsed by major guidelines like **ACC** and **AHA**

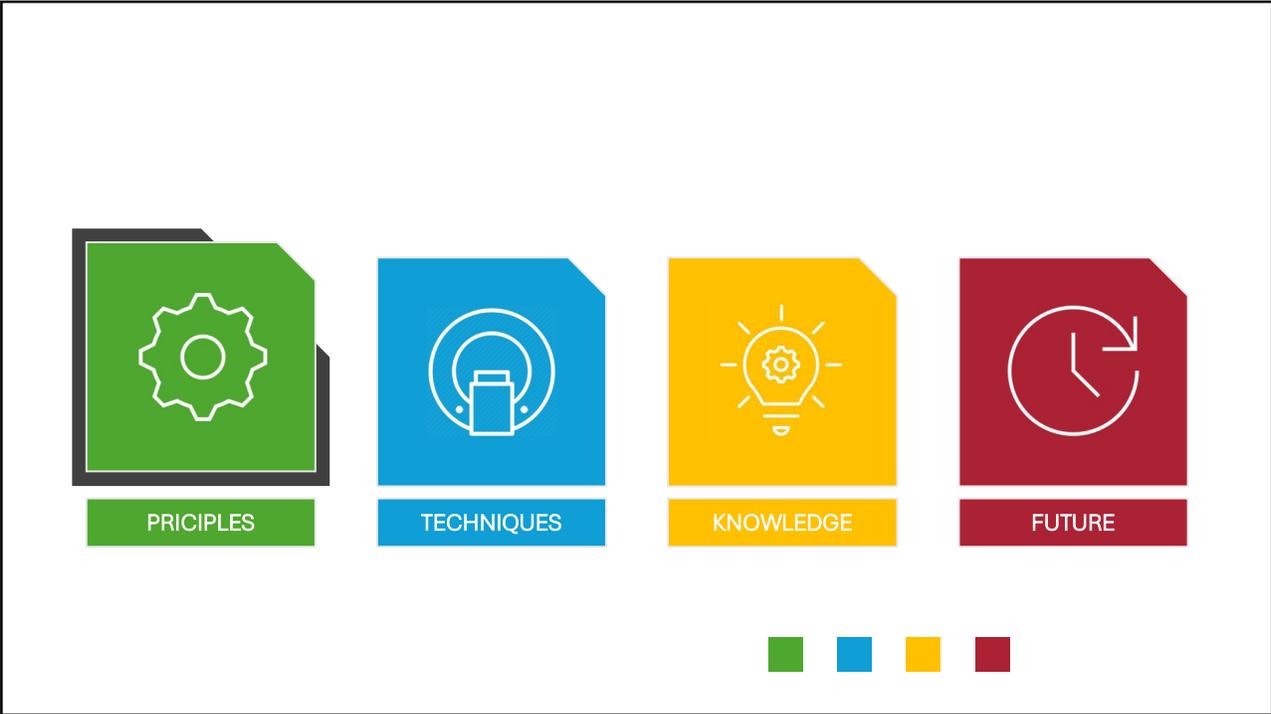
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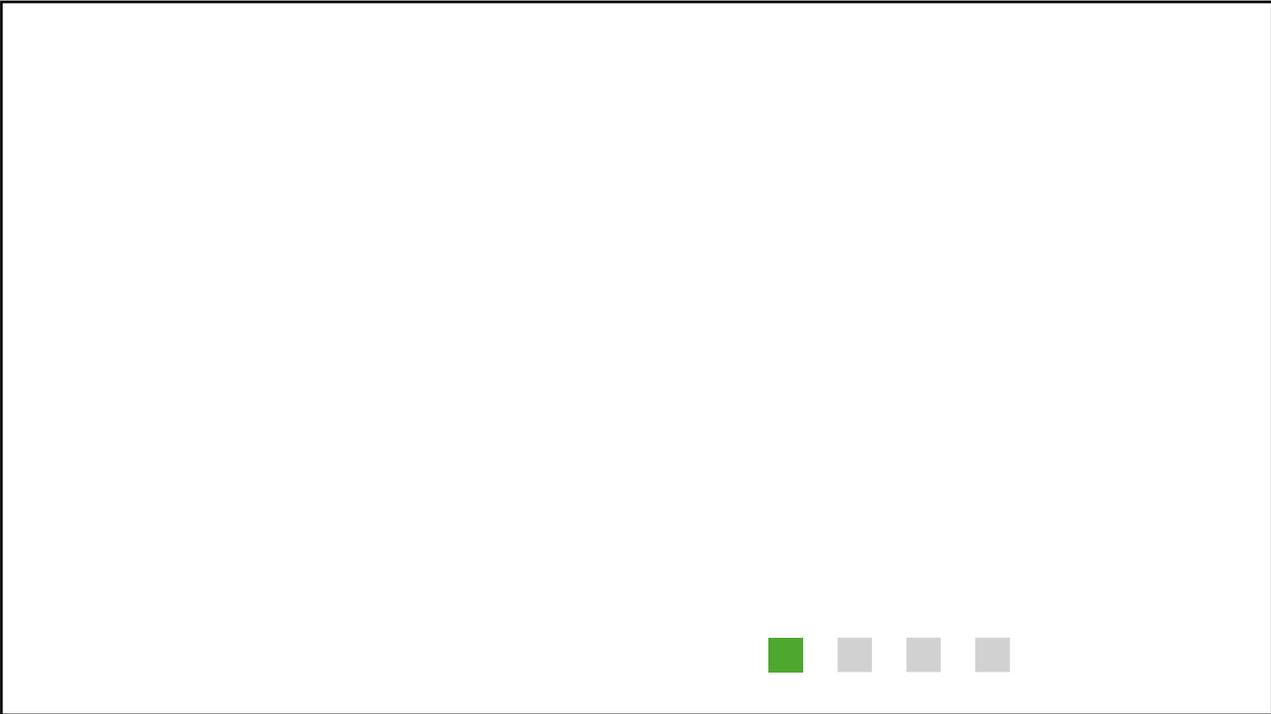
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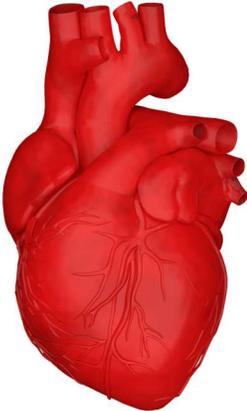
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8

THE CHALLENGE

The heart is in constant motion. The human heart beats over 2.5 billion times in an average lifetime and around 100,000 beats daily



■ ■ ■ ■

9

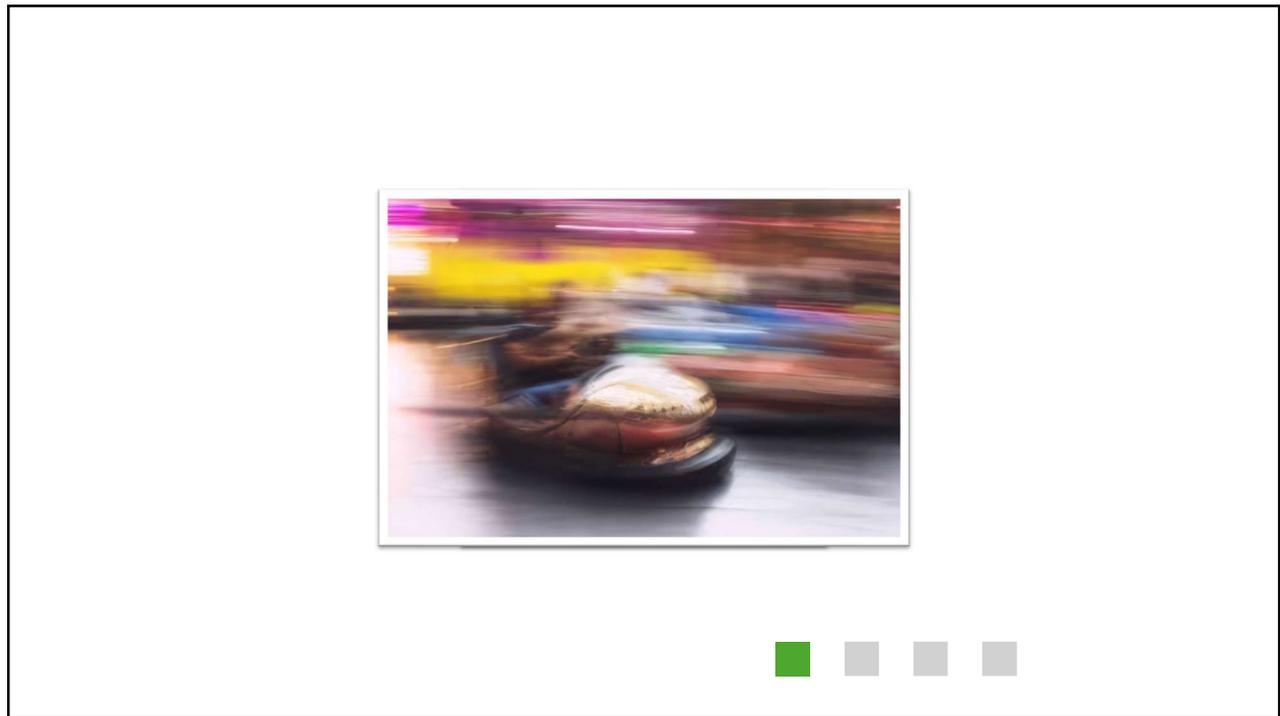
MOTION IS DIFFICULT TO IMAGE

■ ■ ■ ■

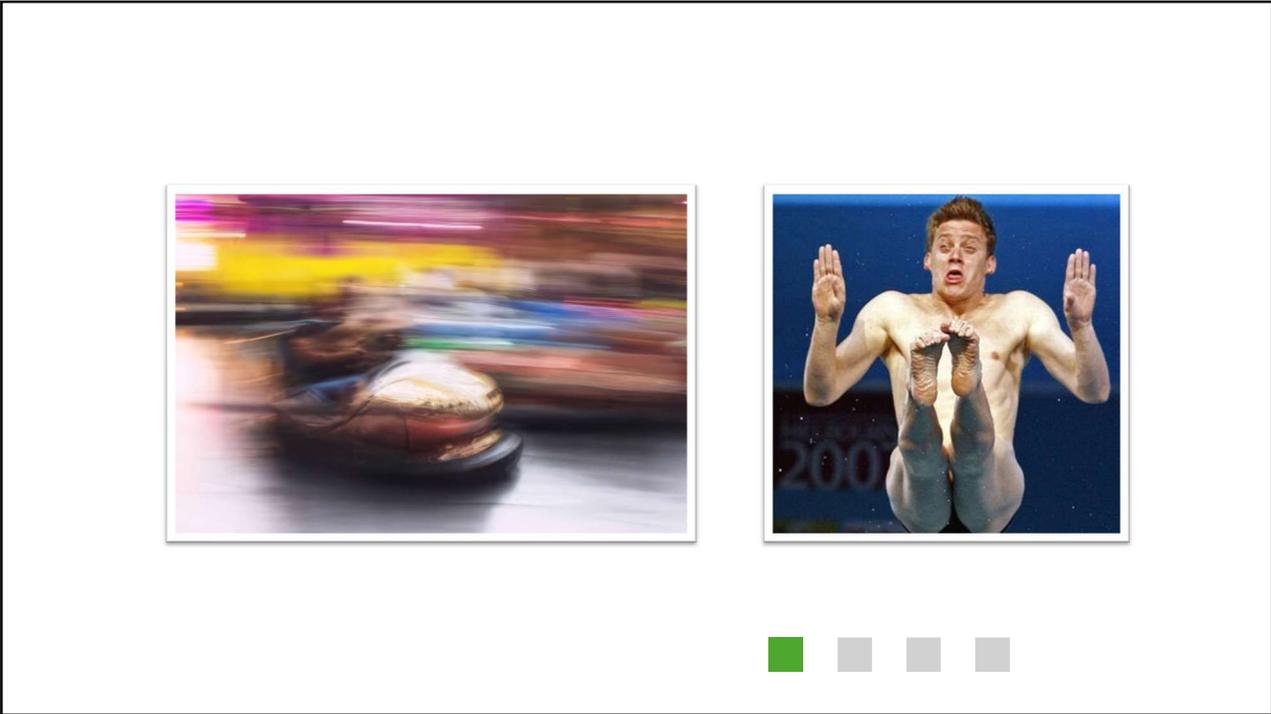
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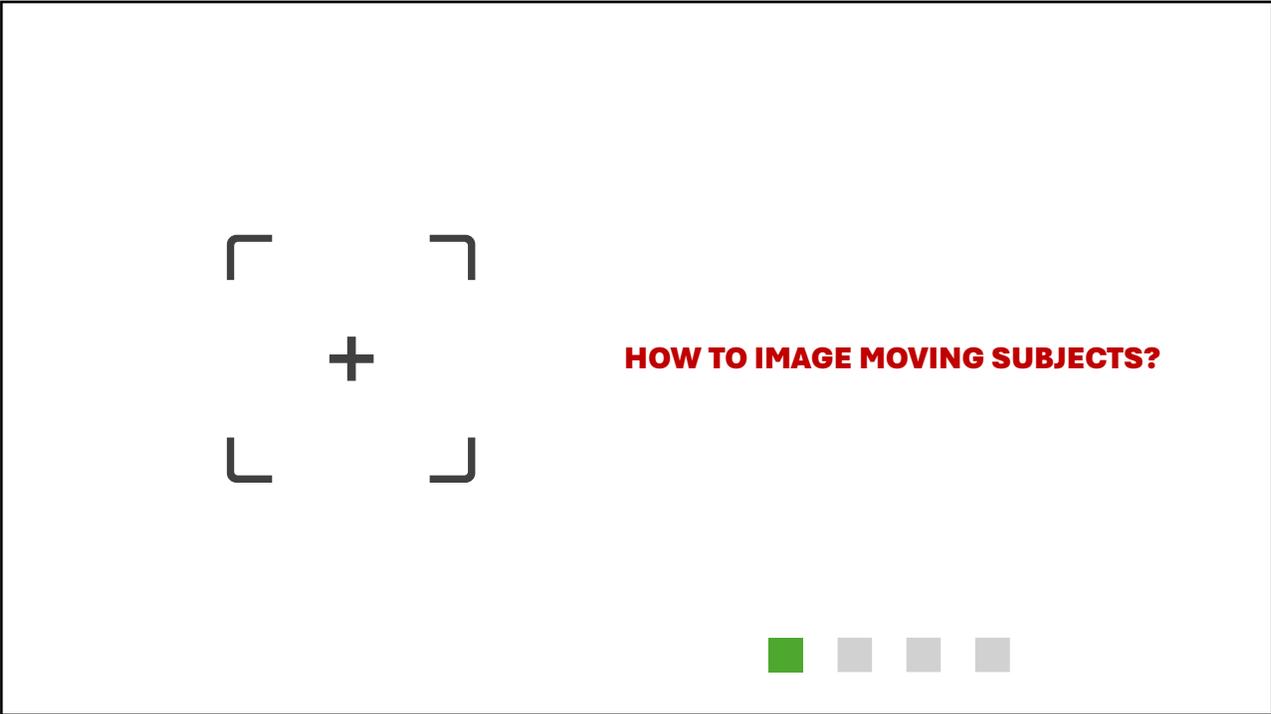
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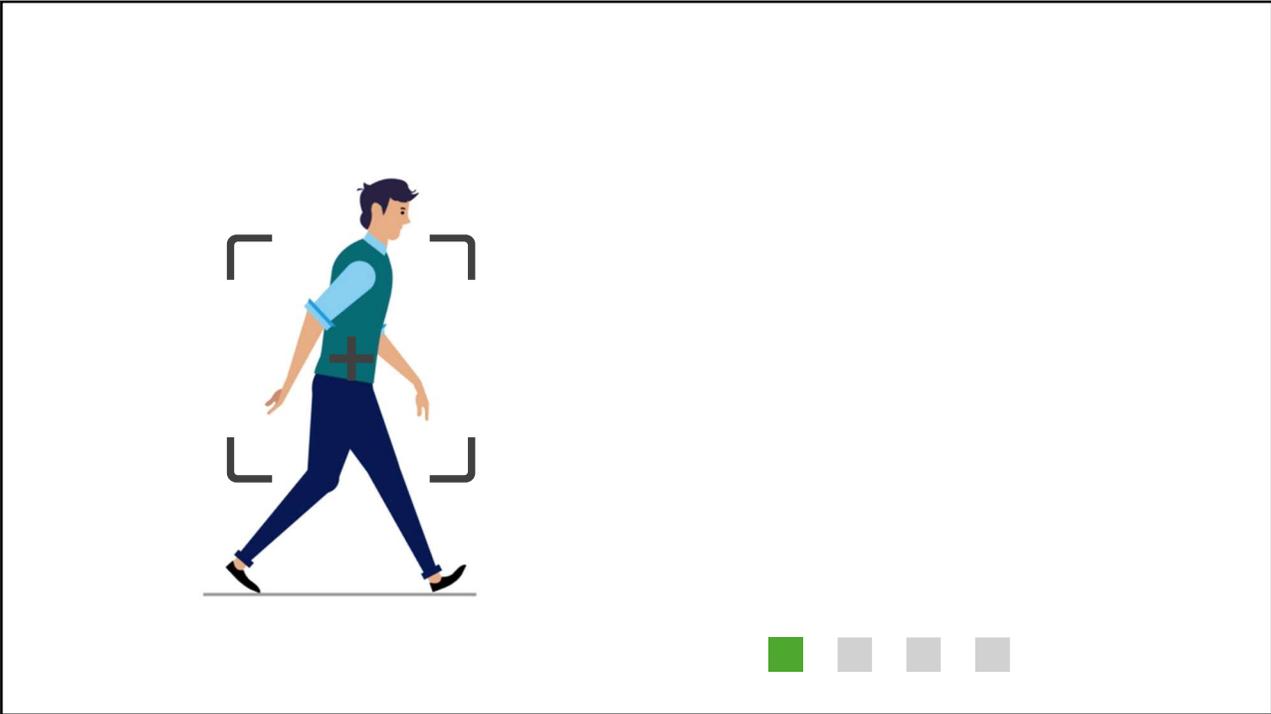
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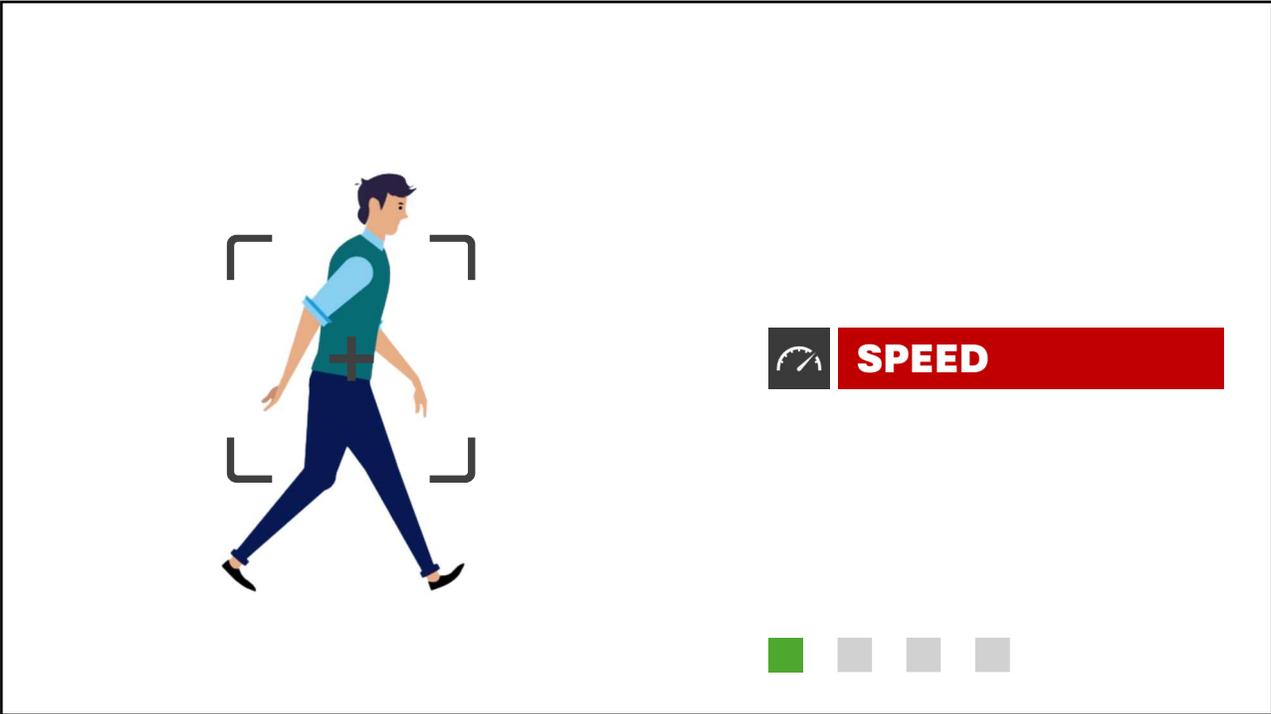
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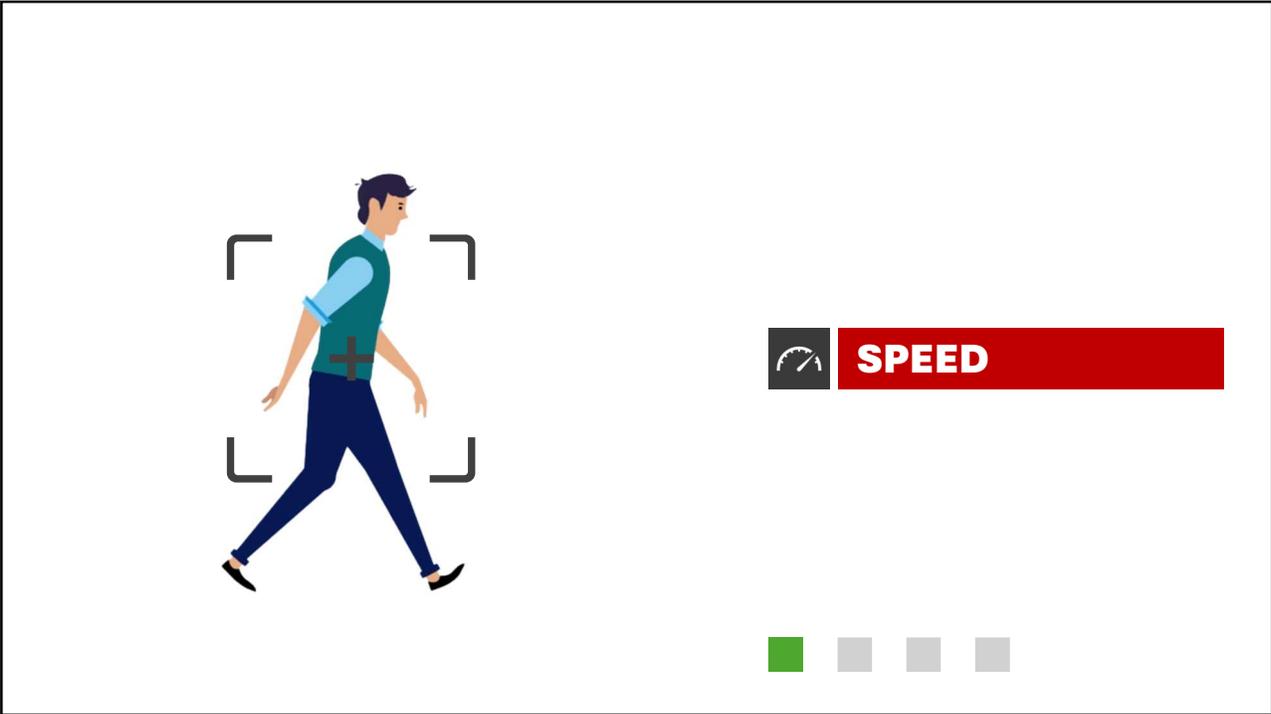
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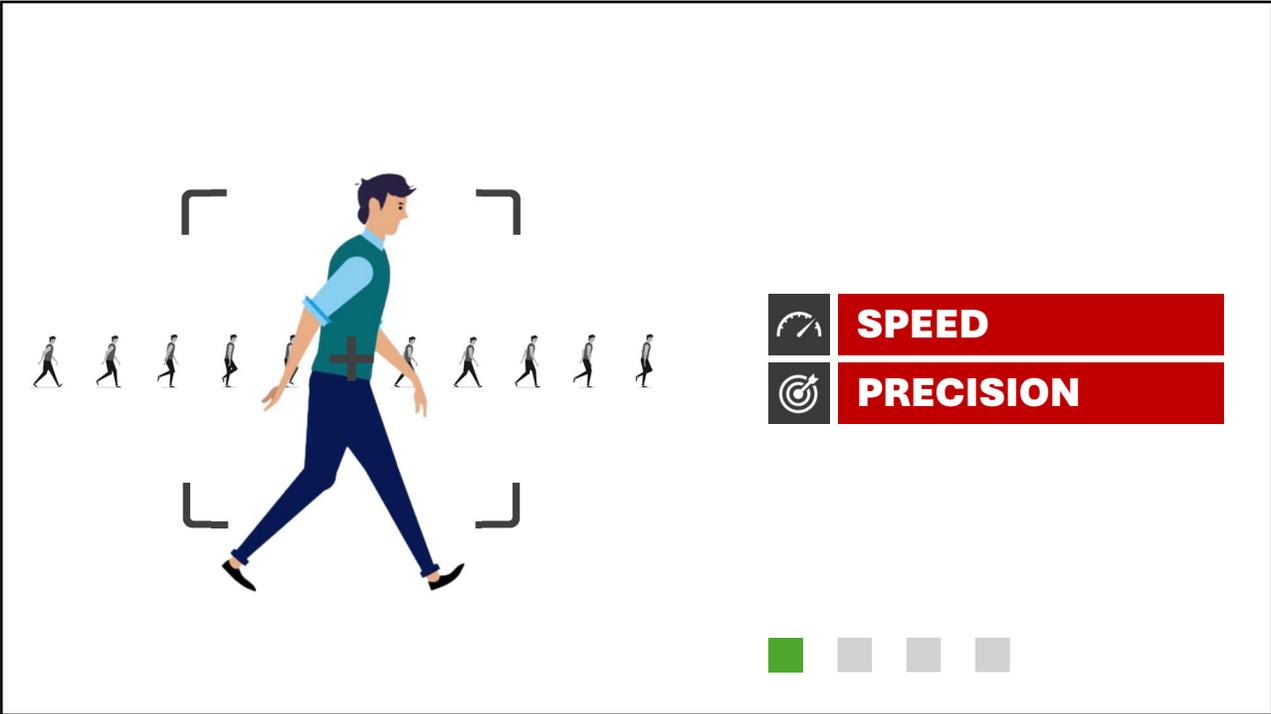
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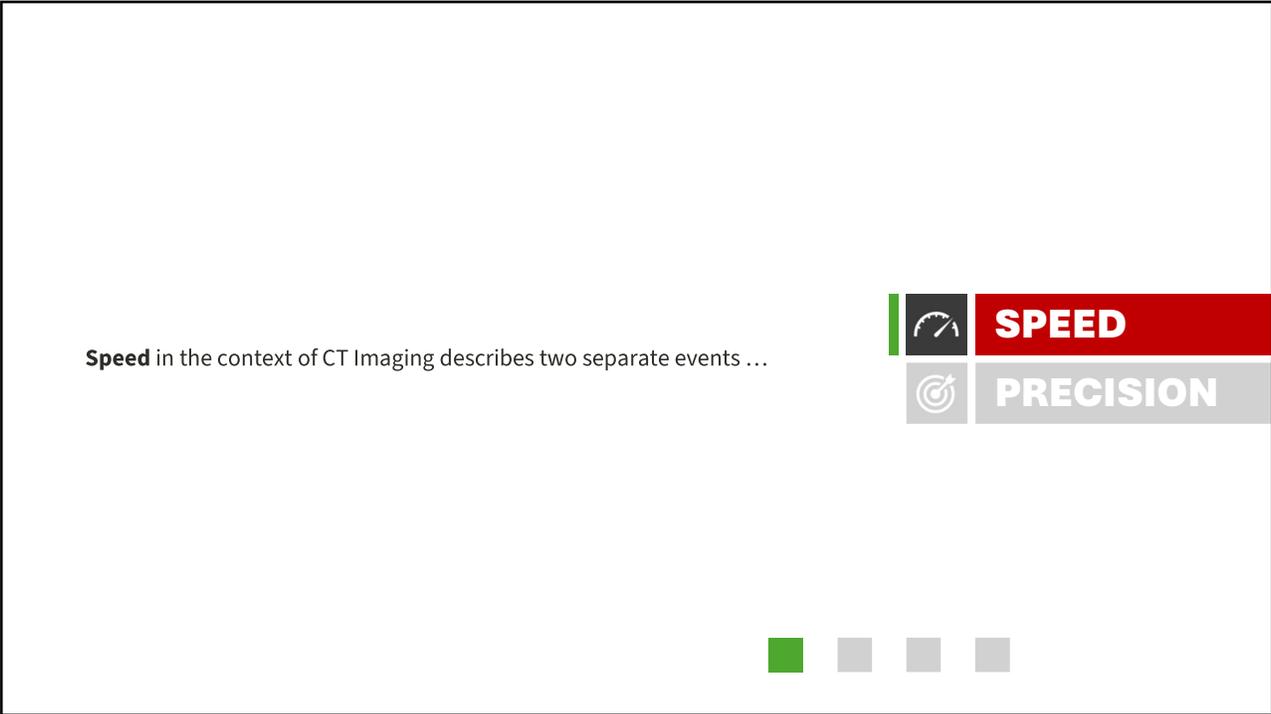
Let us explore how these concepts apply to **Cardiac CT**.

19

20



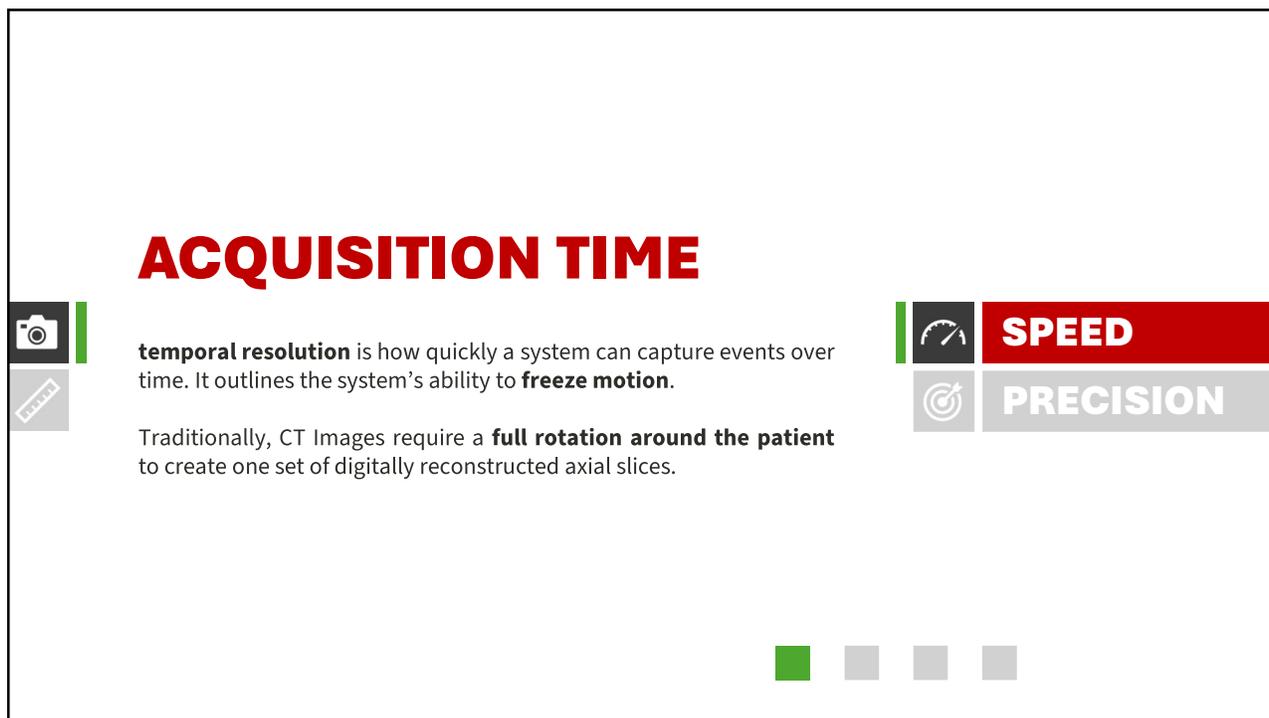
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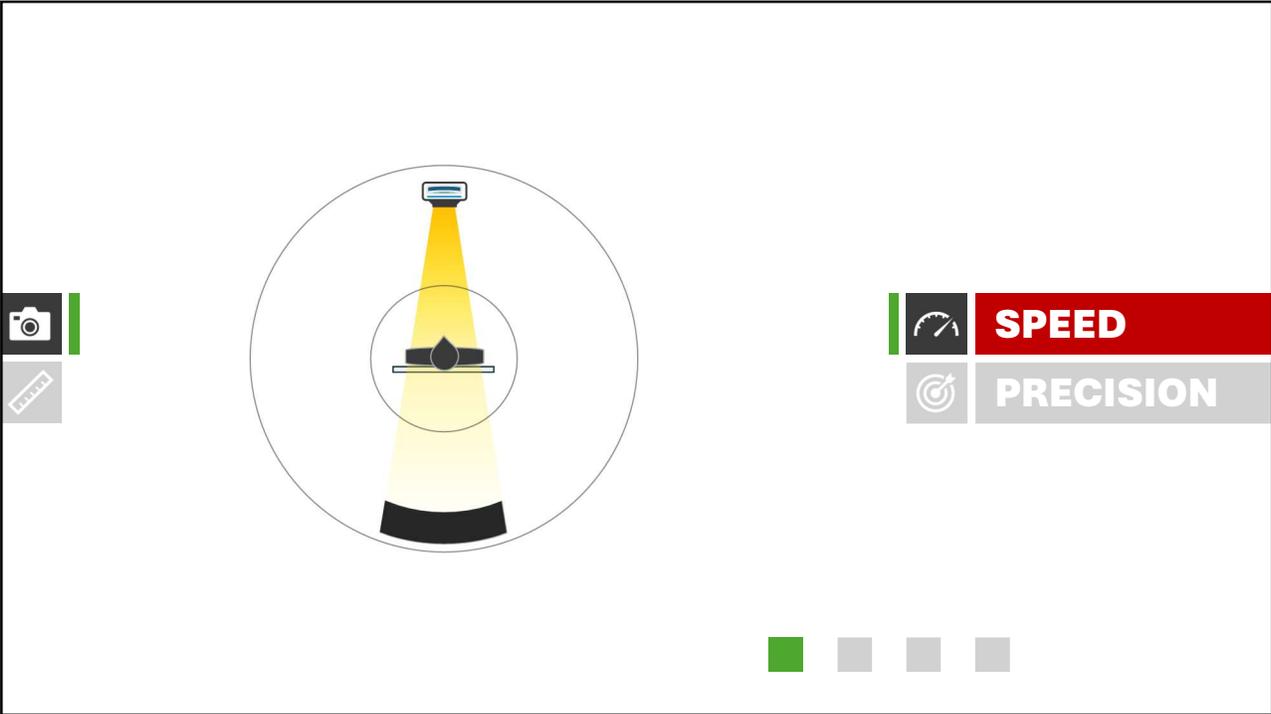
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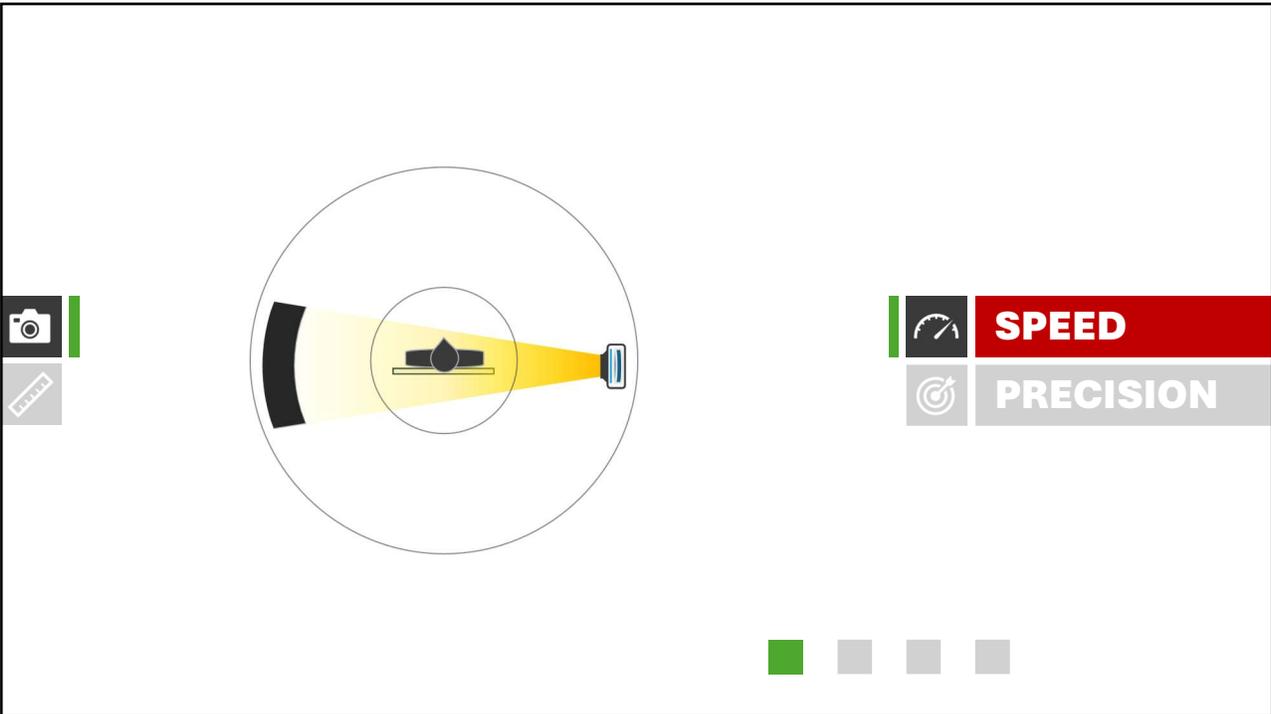
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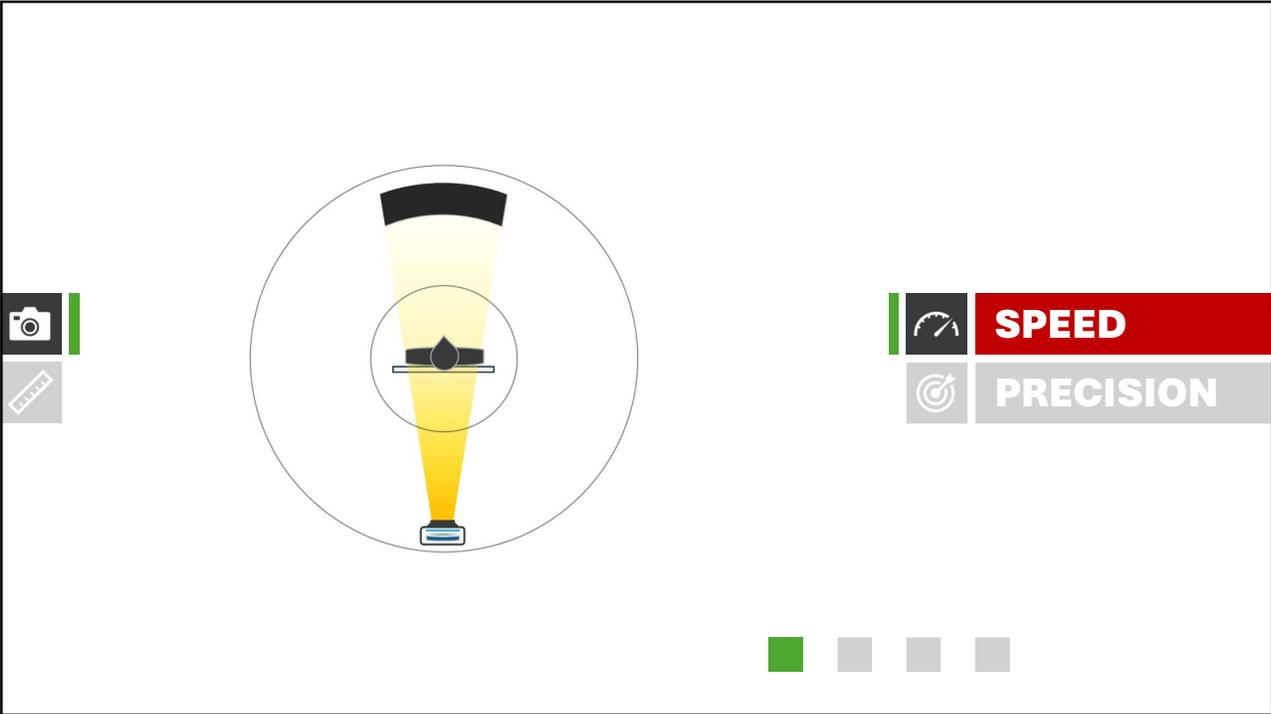
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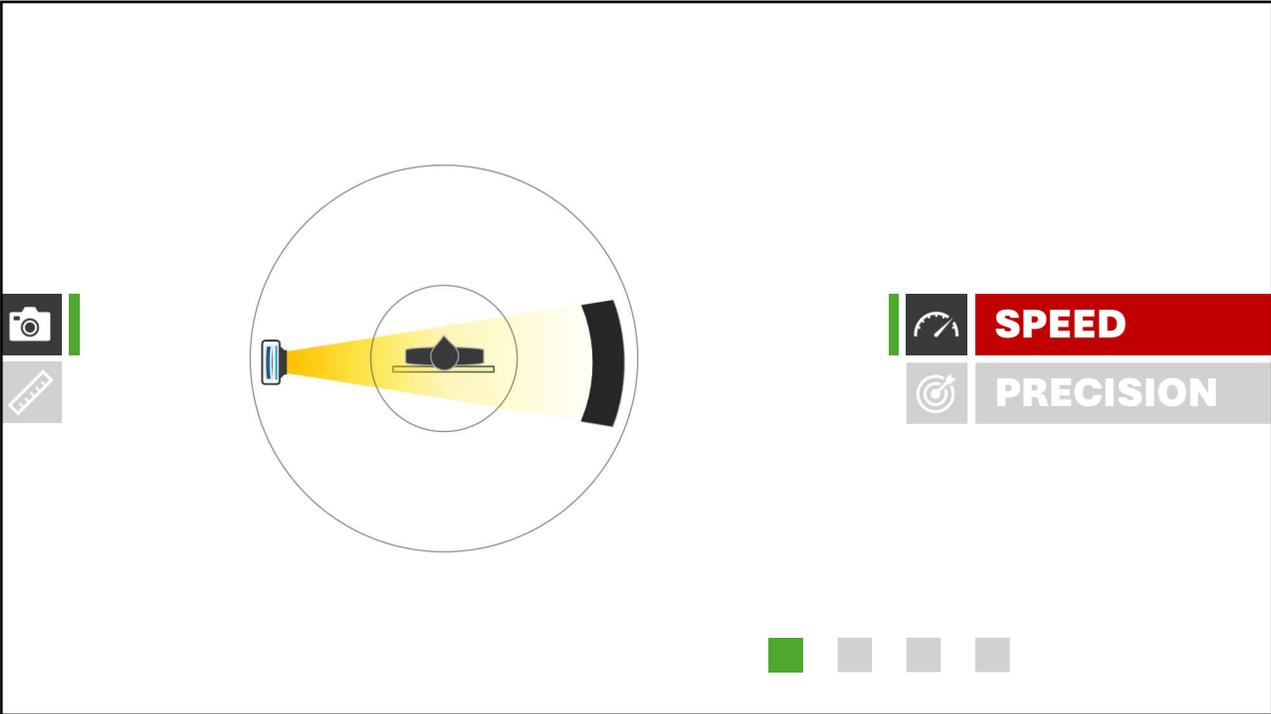
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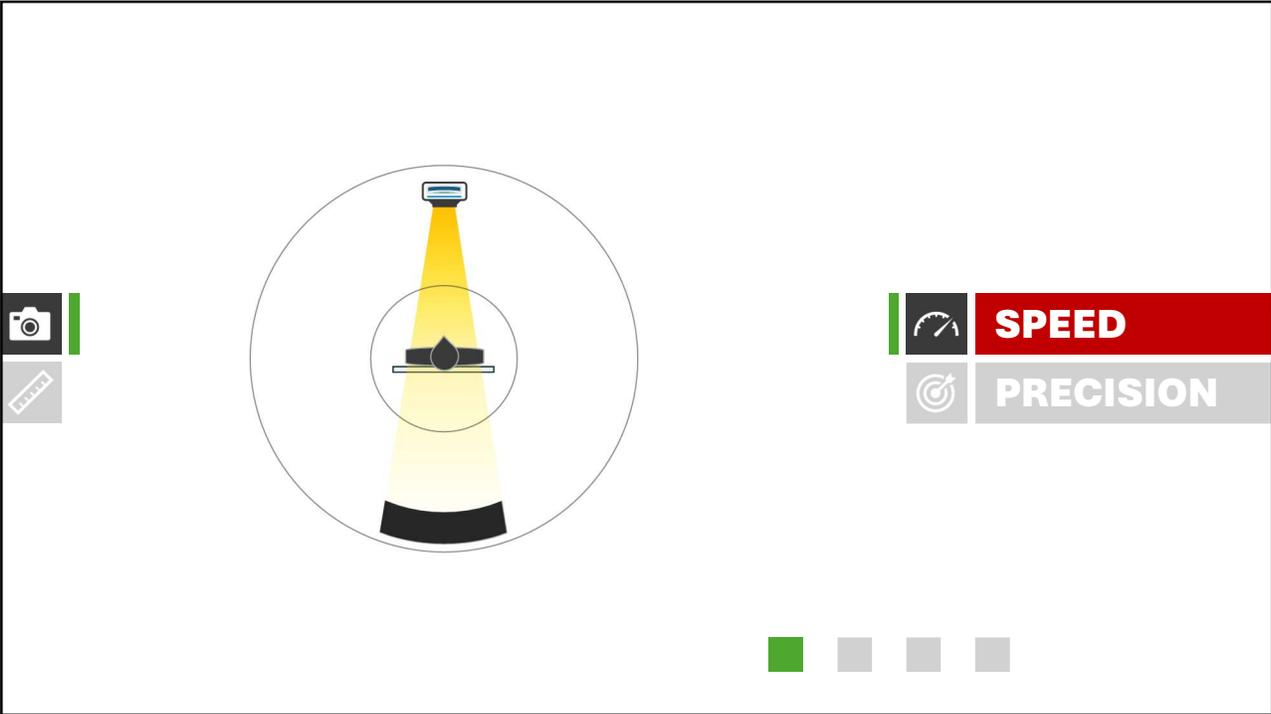
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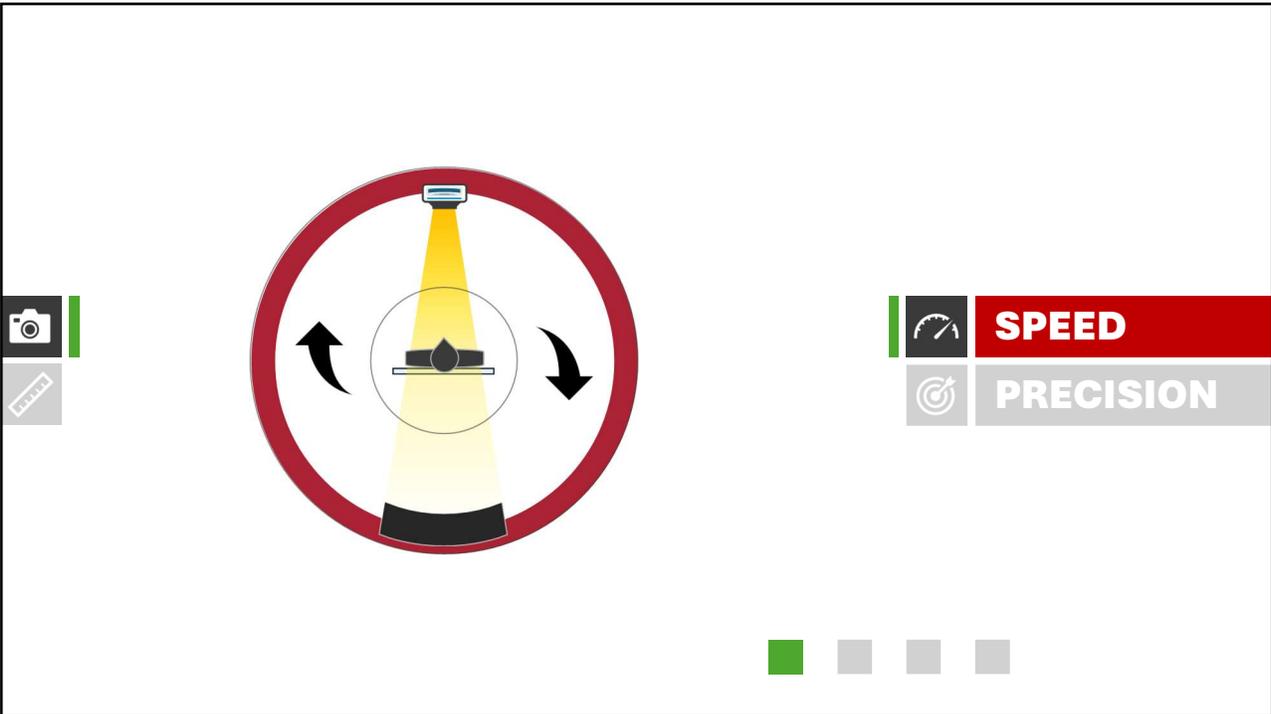
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30

This is known as a **full-scan reconstruction**. It is the reconstruction of slices from a full rotation of the tube around the patient.

SPEED
PRECISION

31

Modern CT scanners can complete a full-scan reconstruction in around **0.275s** or **275ms**.

SPEED
PRECISION

32

However, **this temporal resolution is not sufficient** to freeze cardiac motion. A temporal resolution of around **150ms or less is considered the target** to freeze the rapid motion of the human heart.

Therefore... for cardiac imaging, CT machines **utilize a different acquisition technique** to achieve **better temporal resolutions**.

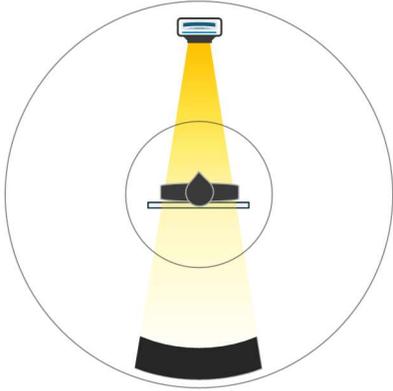
 **SPEED**

 **PRECISION**



33

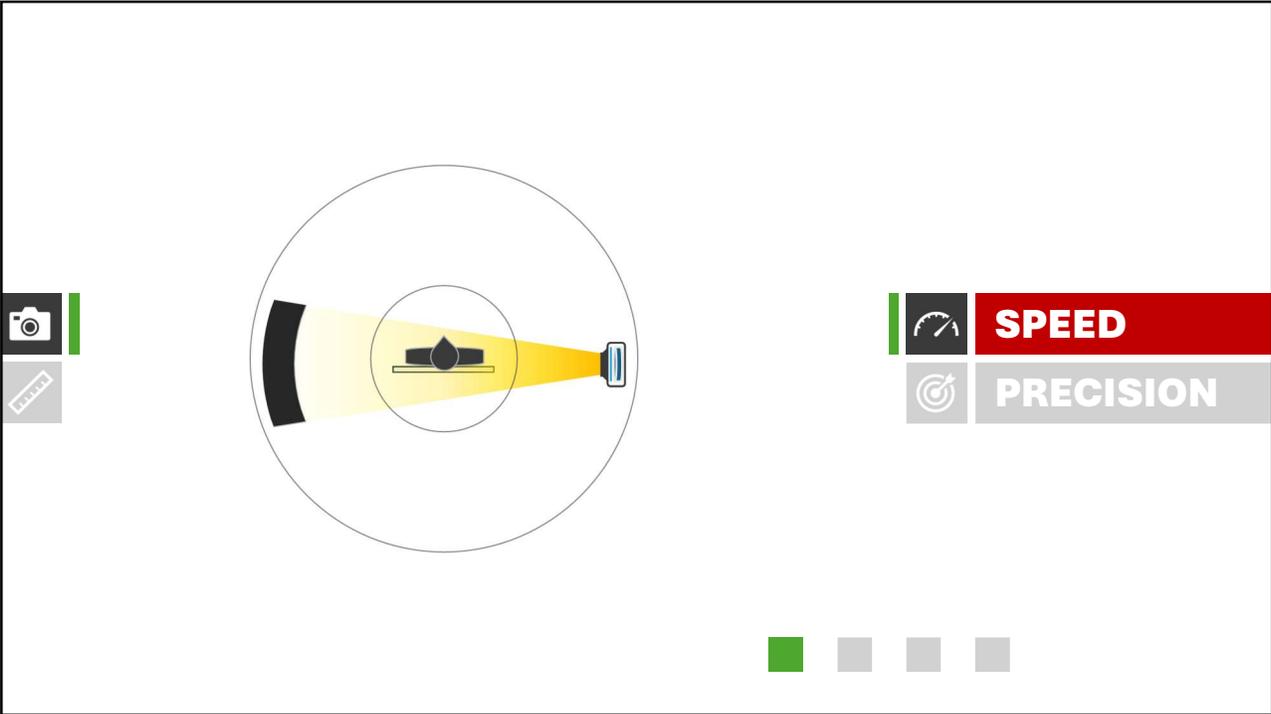


 **SPEED**

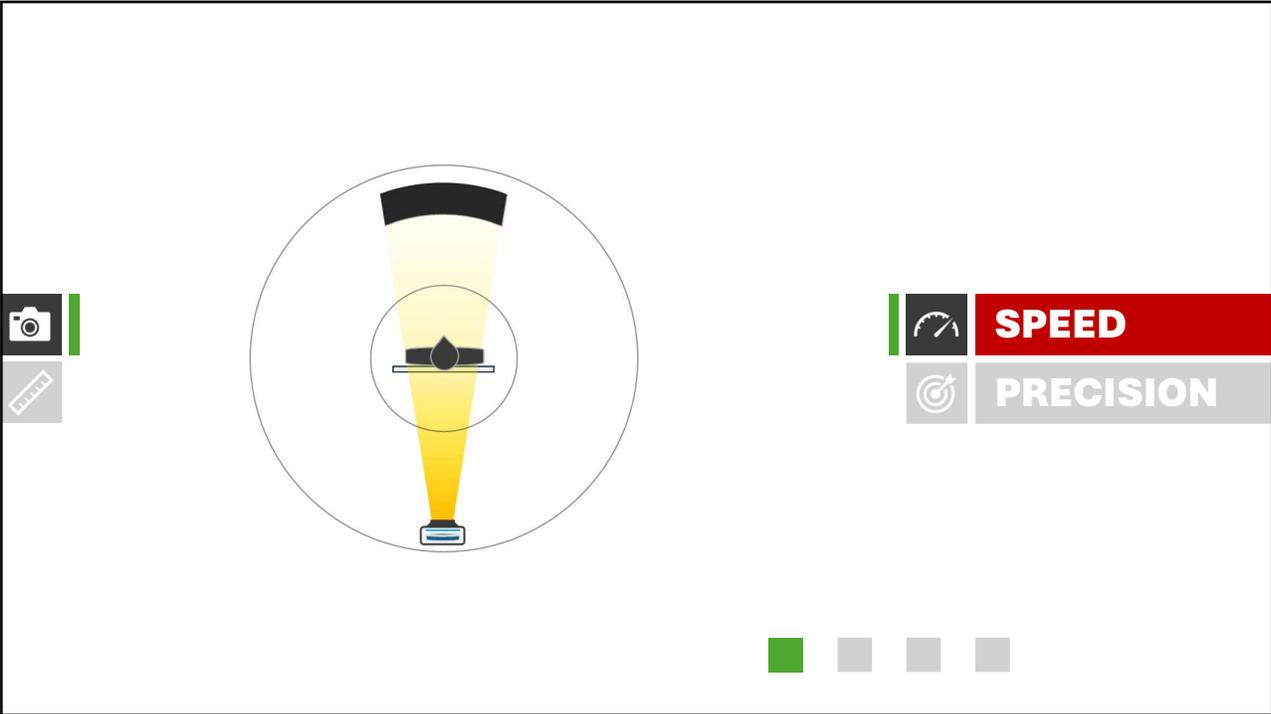
 **PRECISION**



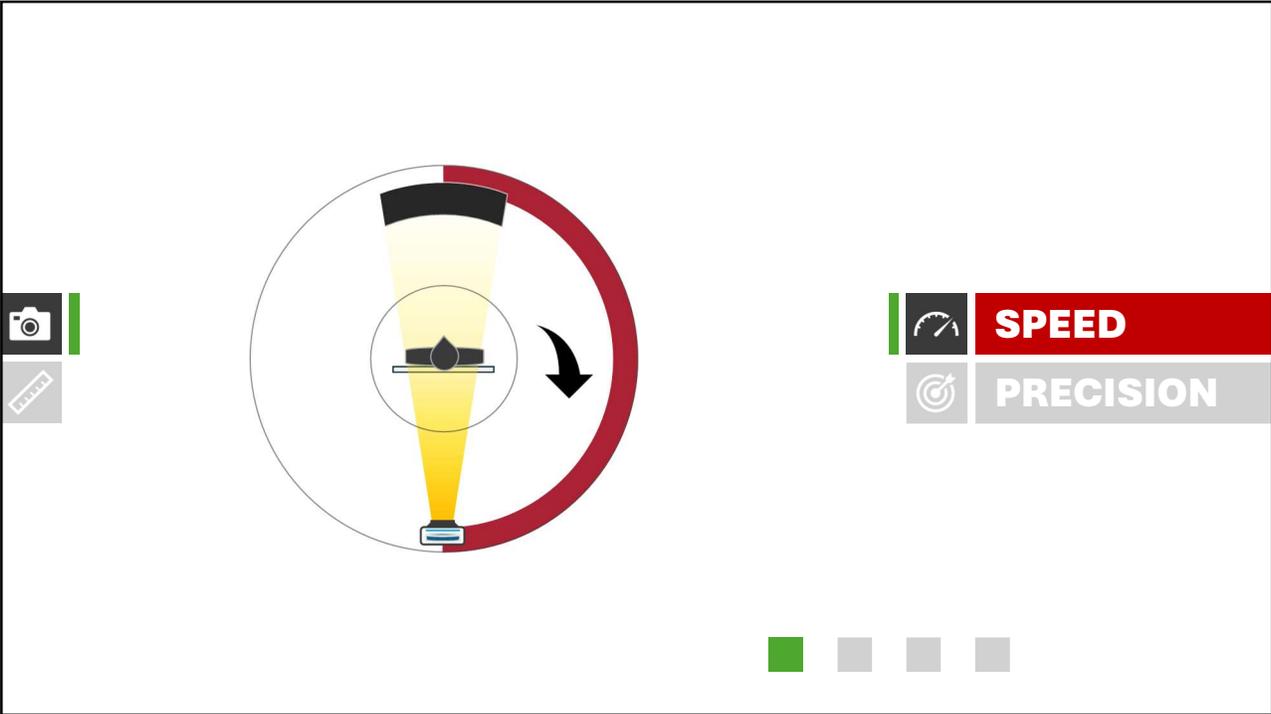
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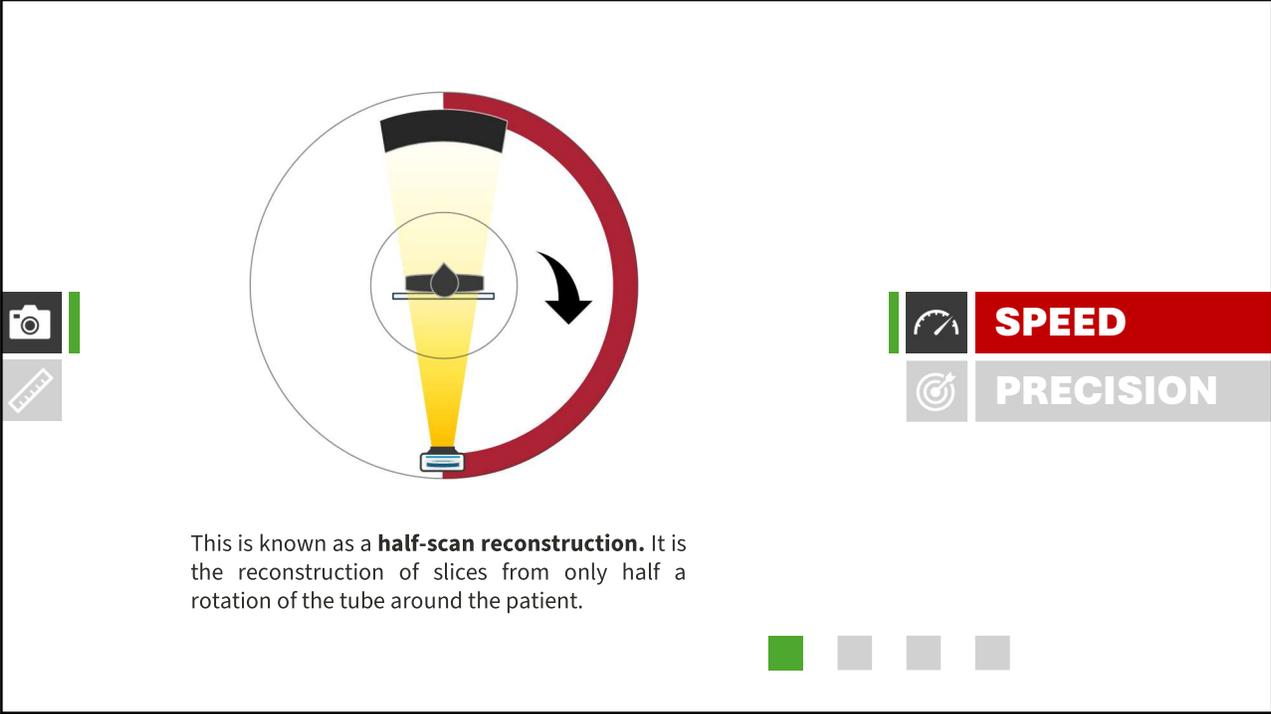
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36



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38

0.137s

SPEED

PRECISION

Half-scan reconstruction cuts the acquisition time to around **0.137s** or **137ms**. At these speeds, cardiac imaging is now possible.

39

SPEED

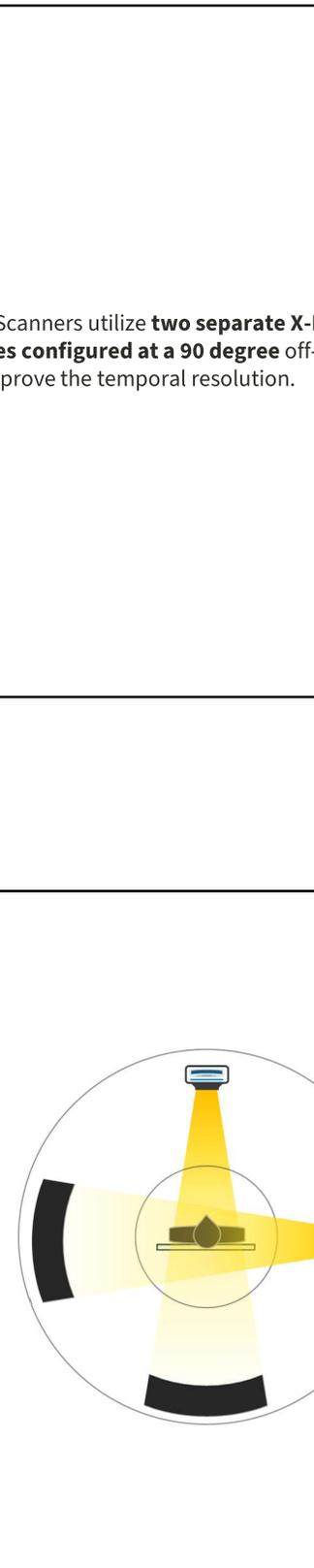
PRECISION

However, it is important to understand that **Half-scan reconstruction is a compromise** as a lesser number of views are used in image reconstruction. It is a gain in temporal resolution at the cost of image quality.

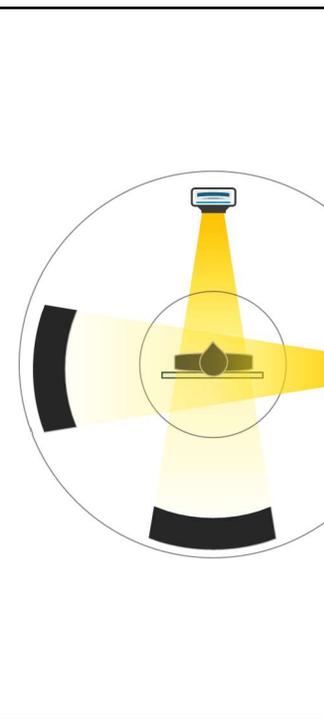
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Some CT Scanners utilize **two separate X-Ray tube & detector assemblies configured at a 90 degree** off-set from one another to further improve the temporal resolution.

SPEED
PRECISION

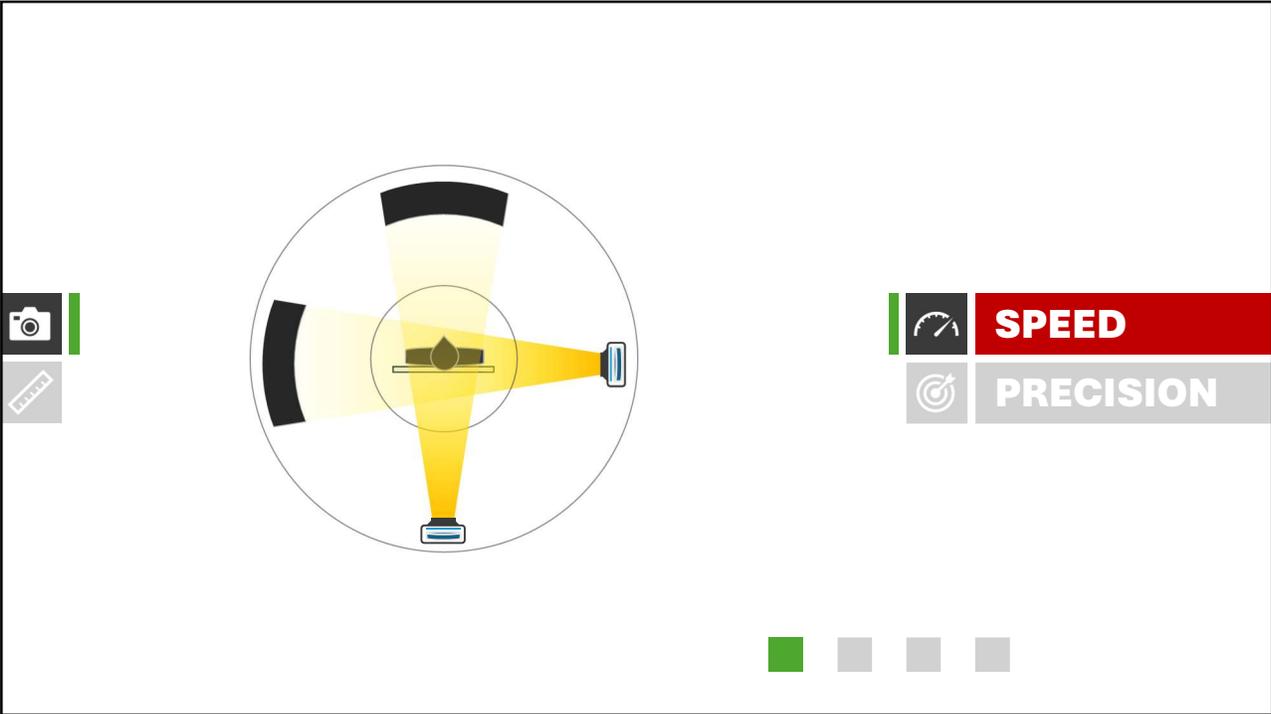


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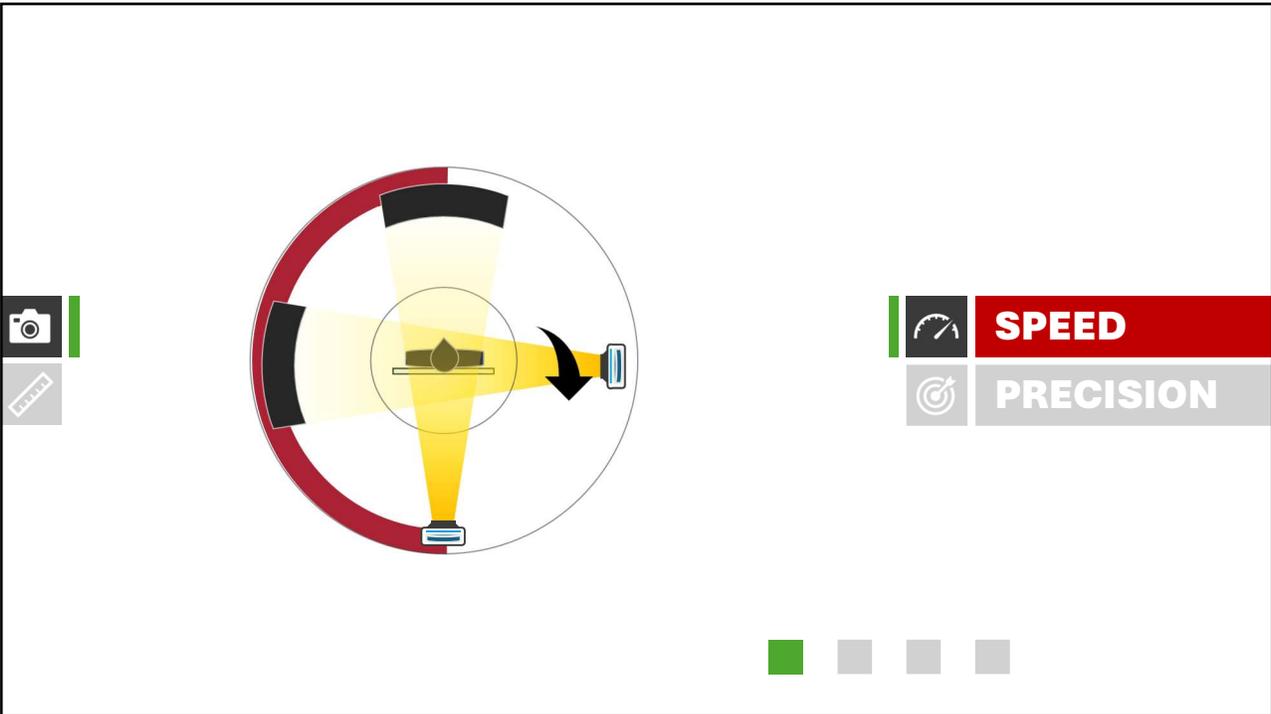


SPEED
PRECISION

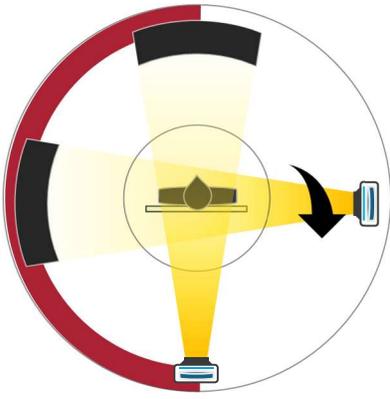
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This is known as **dual source imaging**. It can achieve temporal resolutions of around 75ms, but it comes at the cost of other scanning restrictions.

SPEED
PRECISION

45

Temporal resolution is the most important scanner performance metric for cardiac imaging applications.

However, it is not the only important metric ...

SPEED
PRECISION

46

ACQUISITION COVERAGE



also known as **Z-Axis coverage**, It is the length of scanned area per acquisition. The larger the scanned area, the lesser acquisitions required to complete the entire scan.



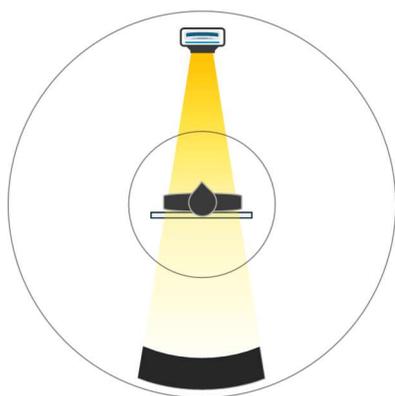
SPEED



PRECISION



47



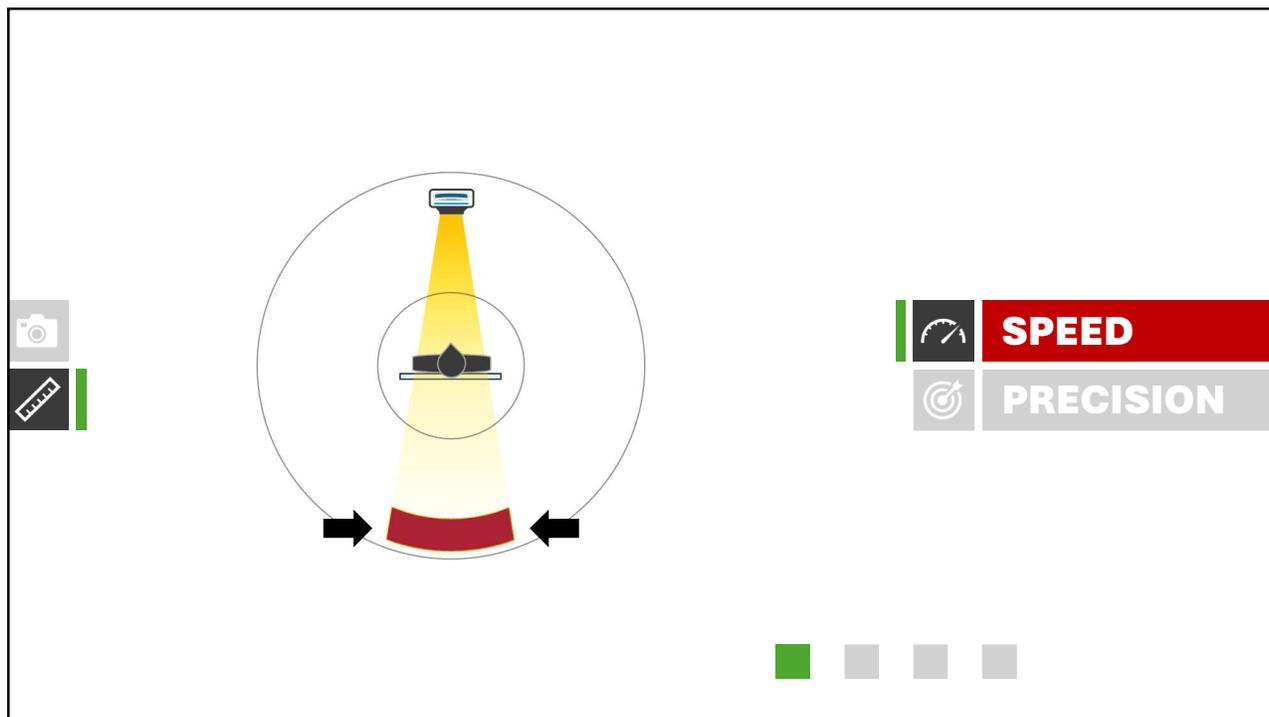
SPEED



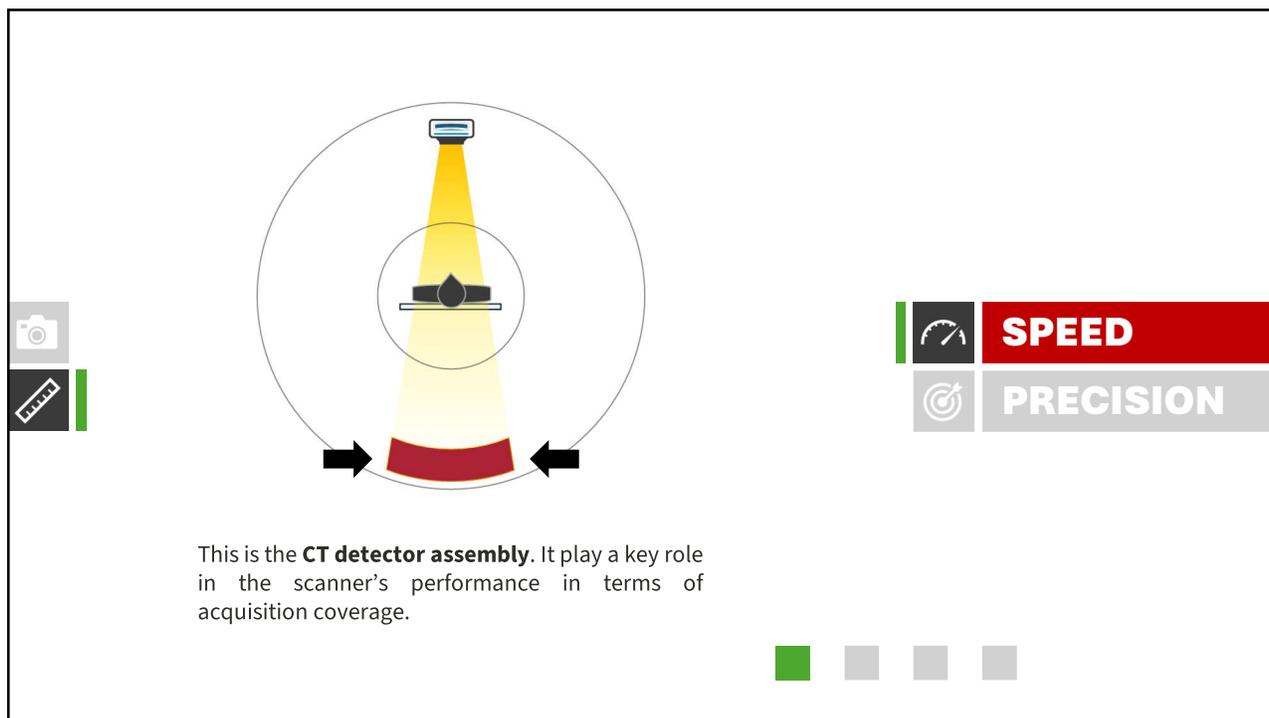
PRECISION



48



49



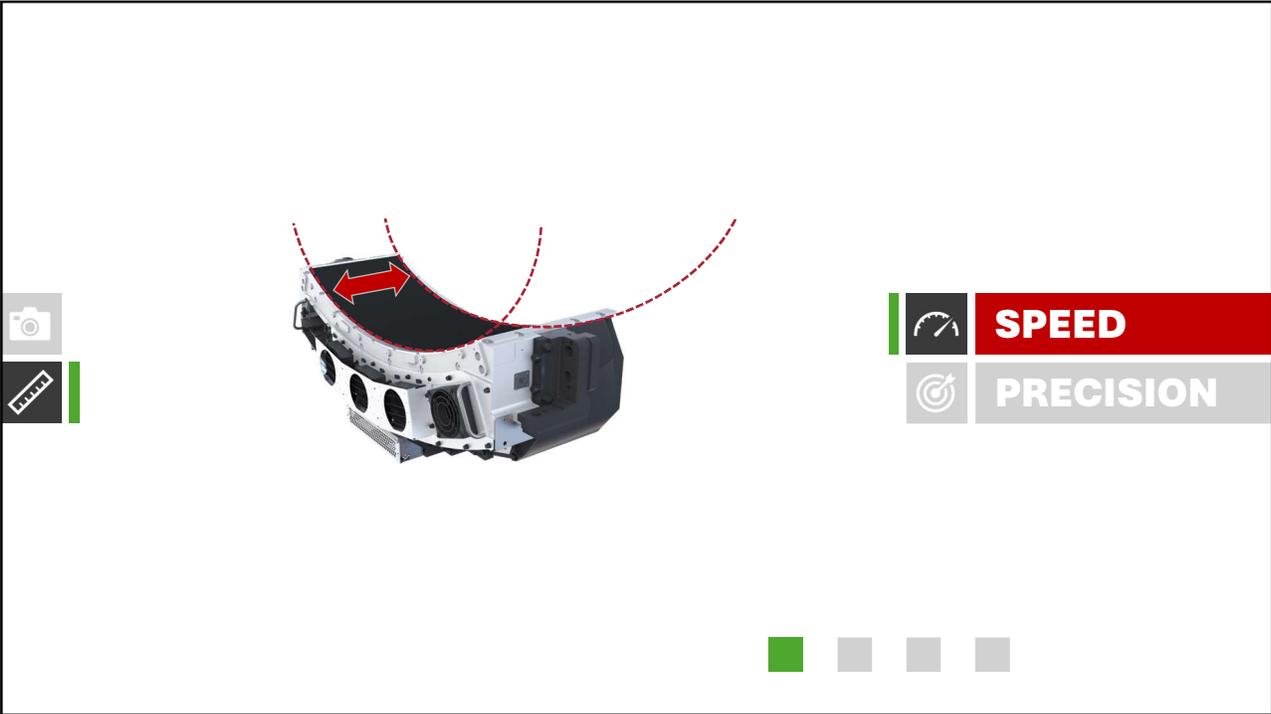
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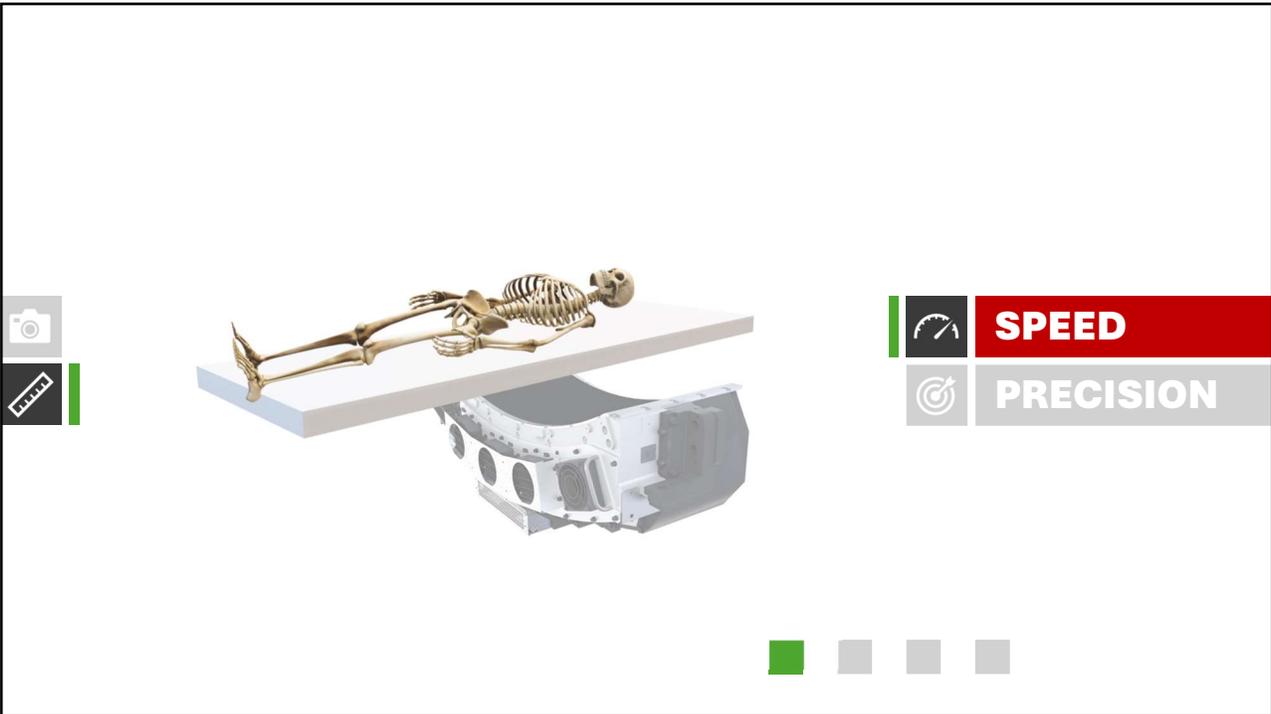
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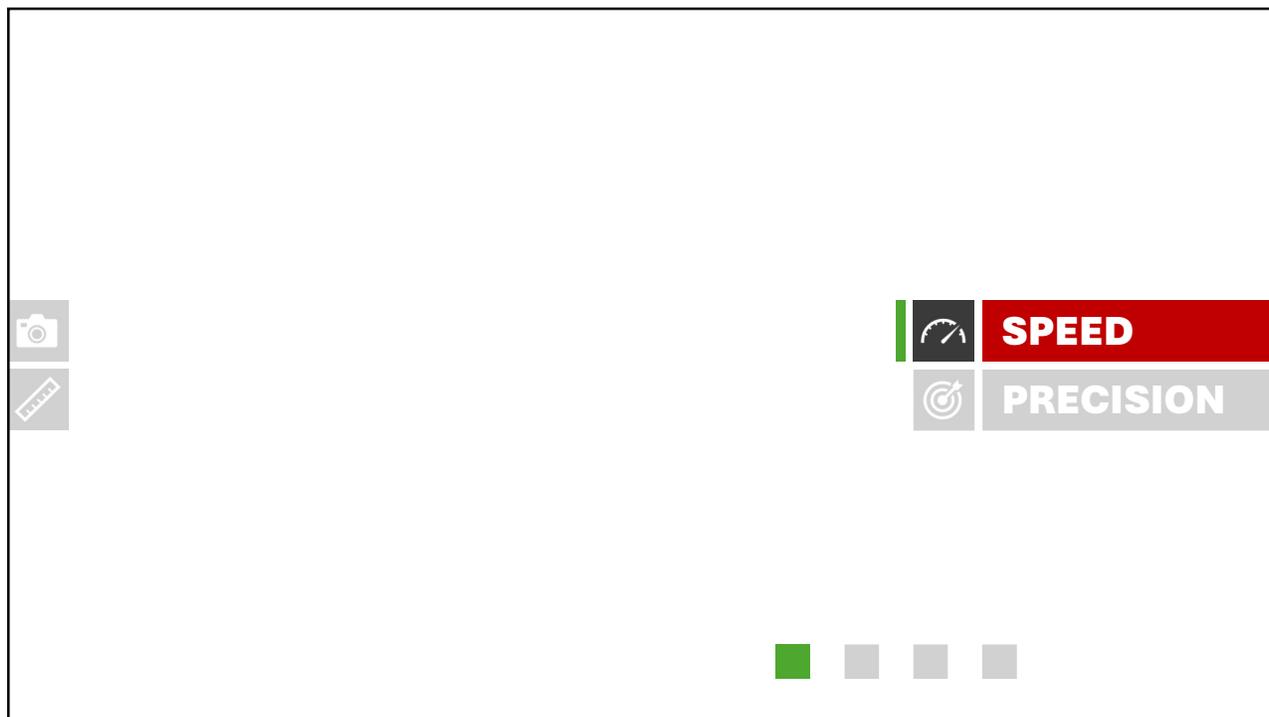
The wider the detector assembly, the larger the acquisition coverage. Therefore, **less acquisitions are necessary** to complete the entire scan.

55

The wider the detector assembly, the larger the acquisition coverage. Therefore, **less acquisitions are necessary** to complete the entire scan.

Larger CT detector make it possible to **image the entire human heart in a single acquisition**, and a single heartbeat. Improving scan speeds and minimizing artifacts.

56



57

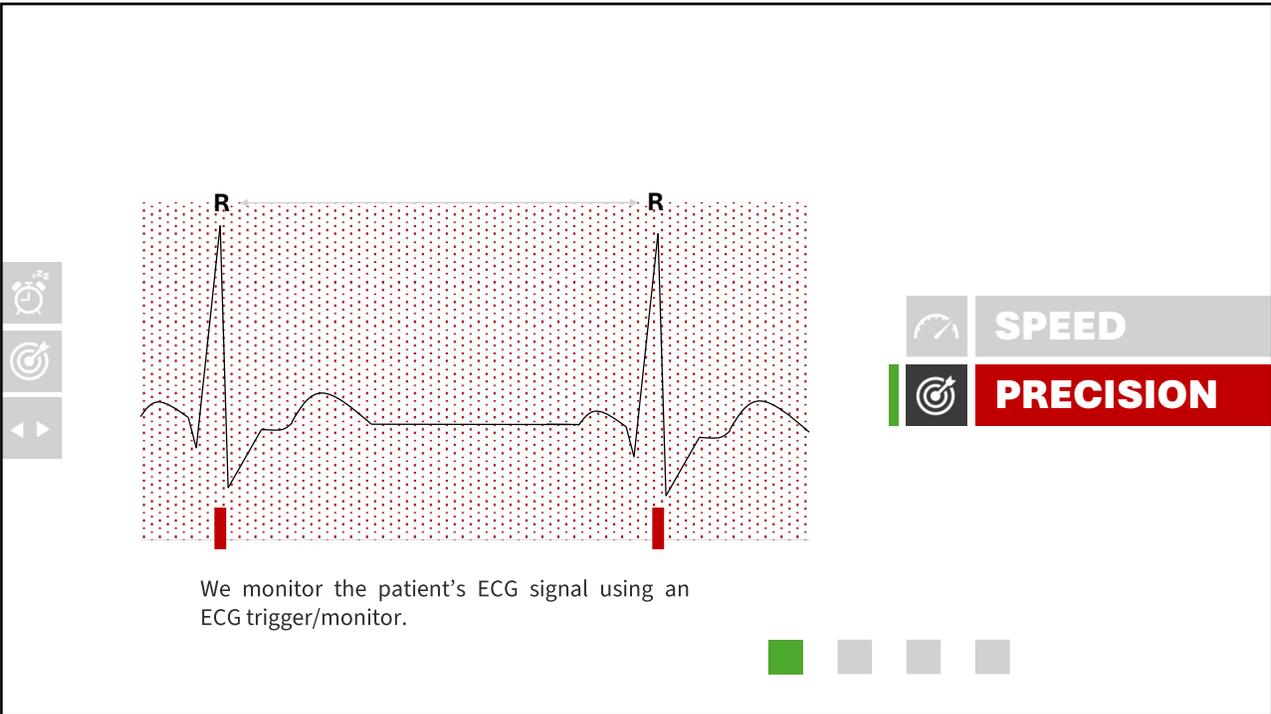
Precision in the context of Cardiac CT Imaging the ability to image any specific part (or phase) of the cardiac cycle, or the entire cycle. This is by **utilizing the patient's ECG signal to guide the exposure.**

This process is called **ECG-Gating** and there are multiple gating methods and techniques ...

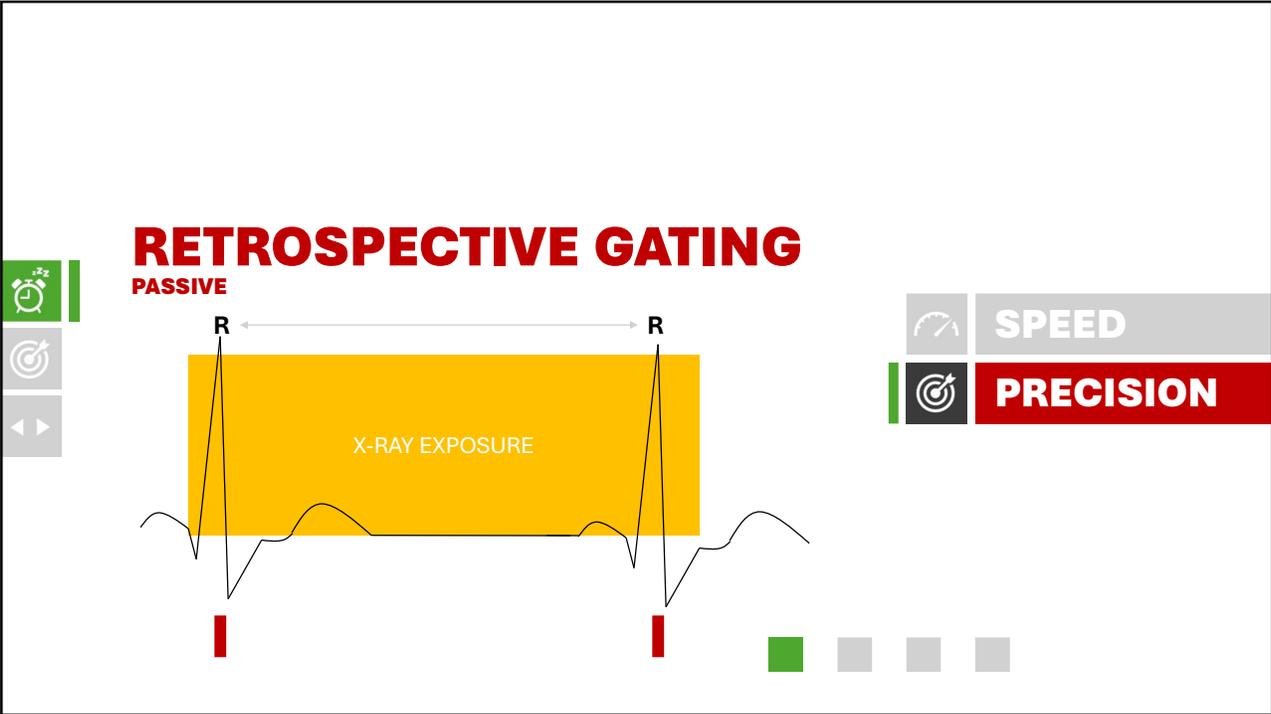
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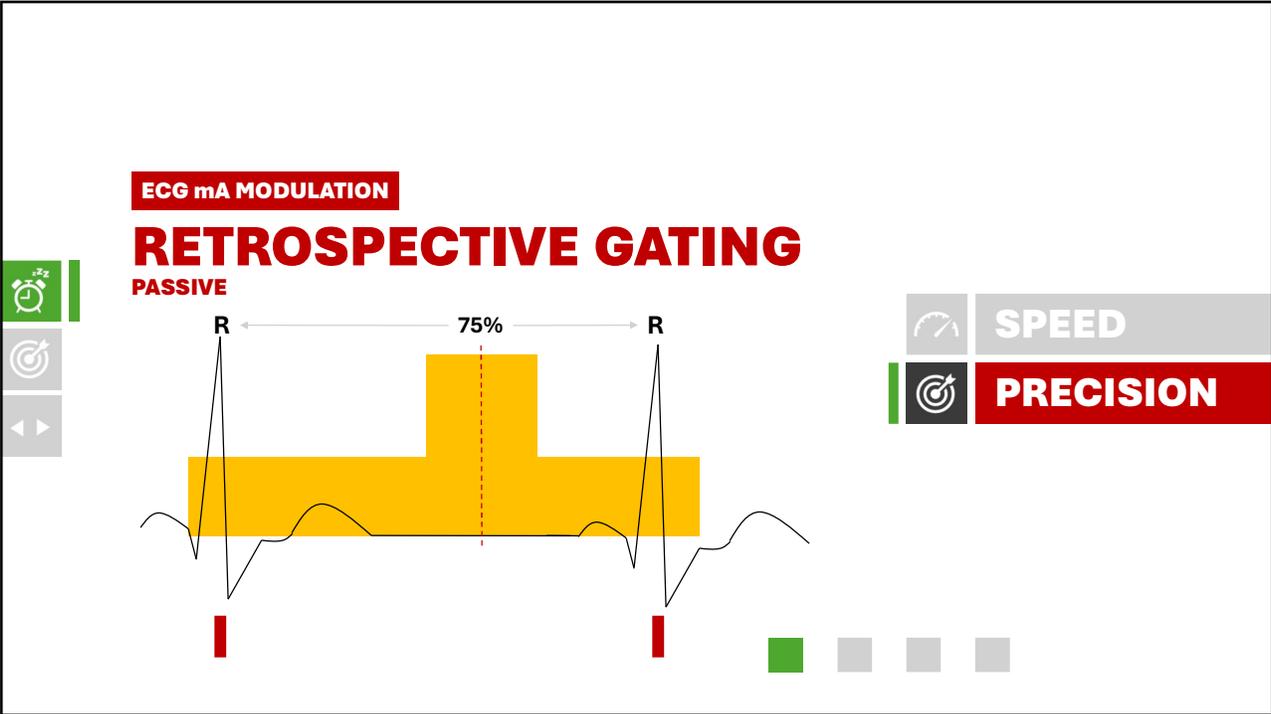
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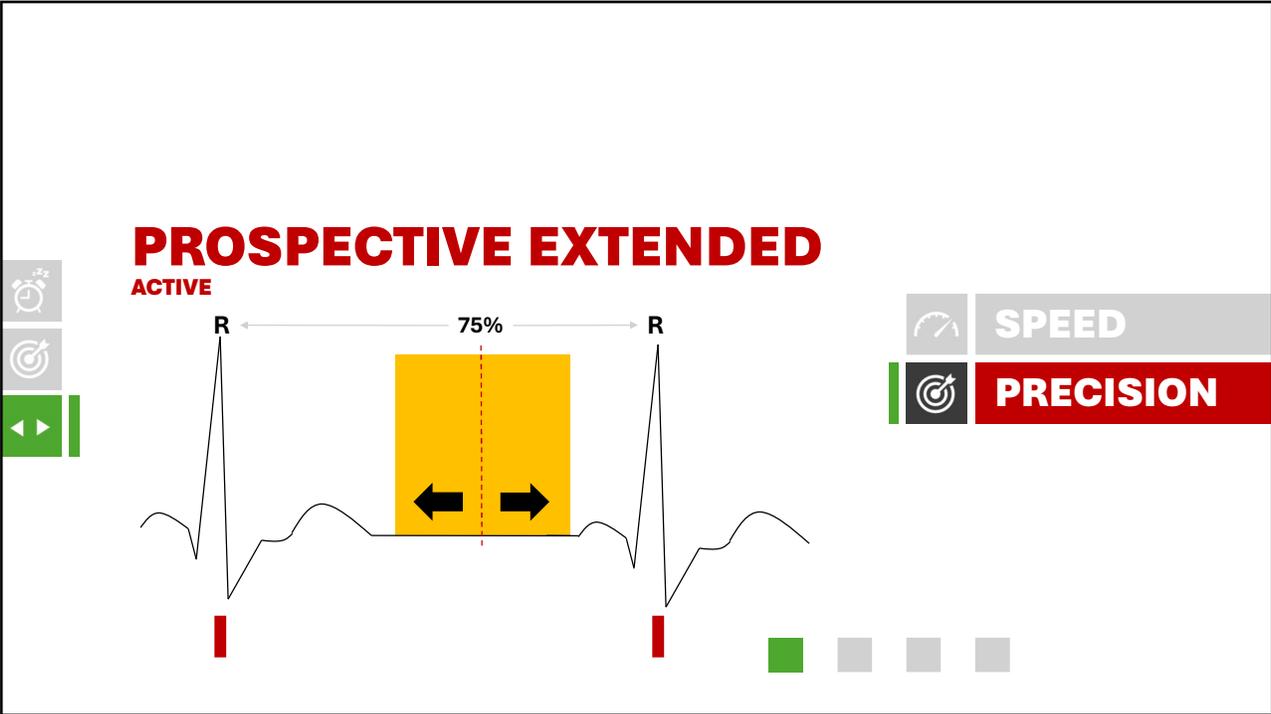
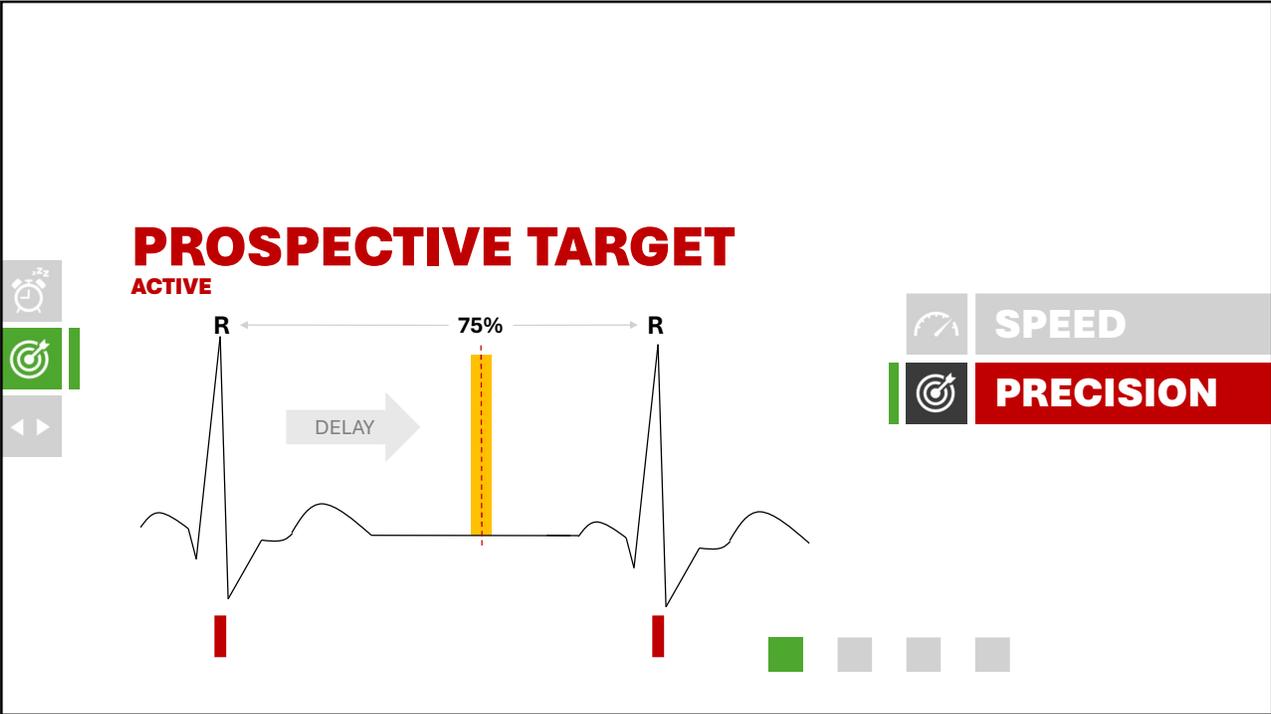
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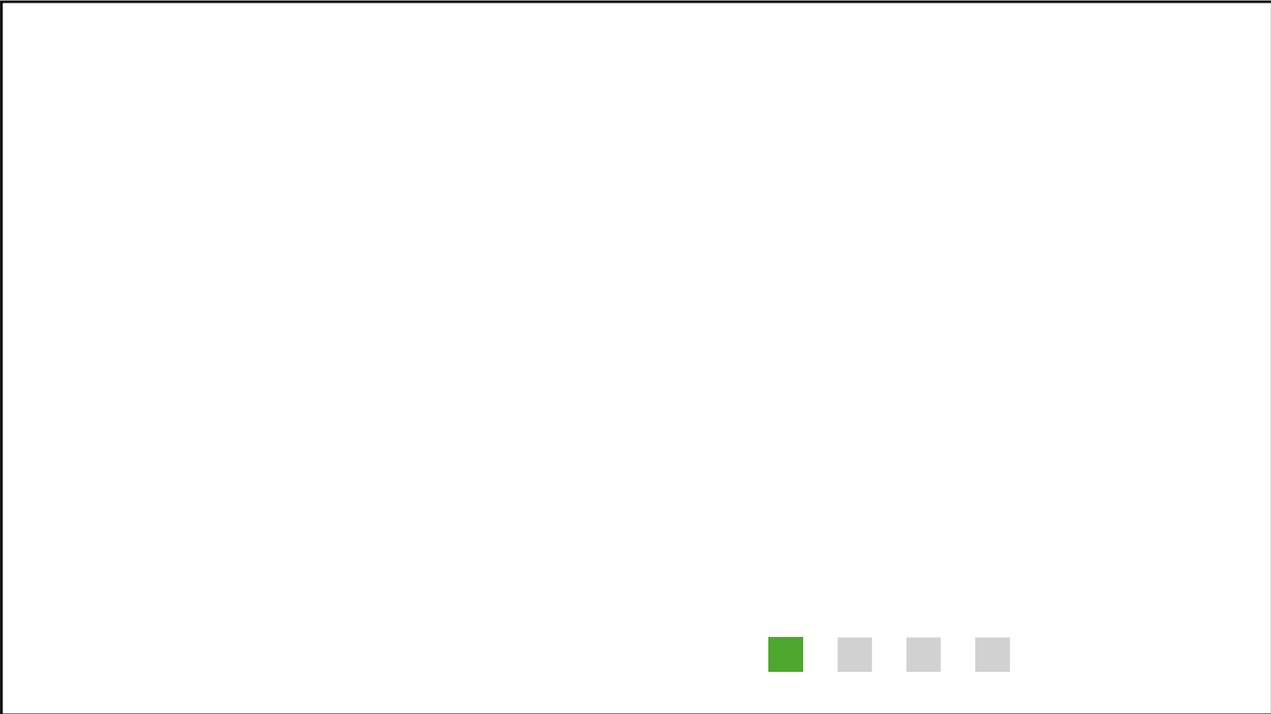


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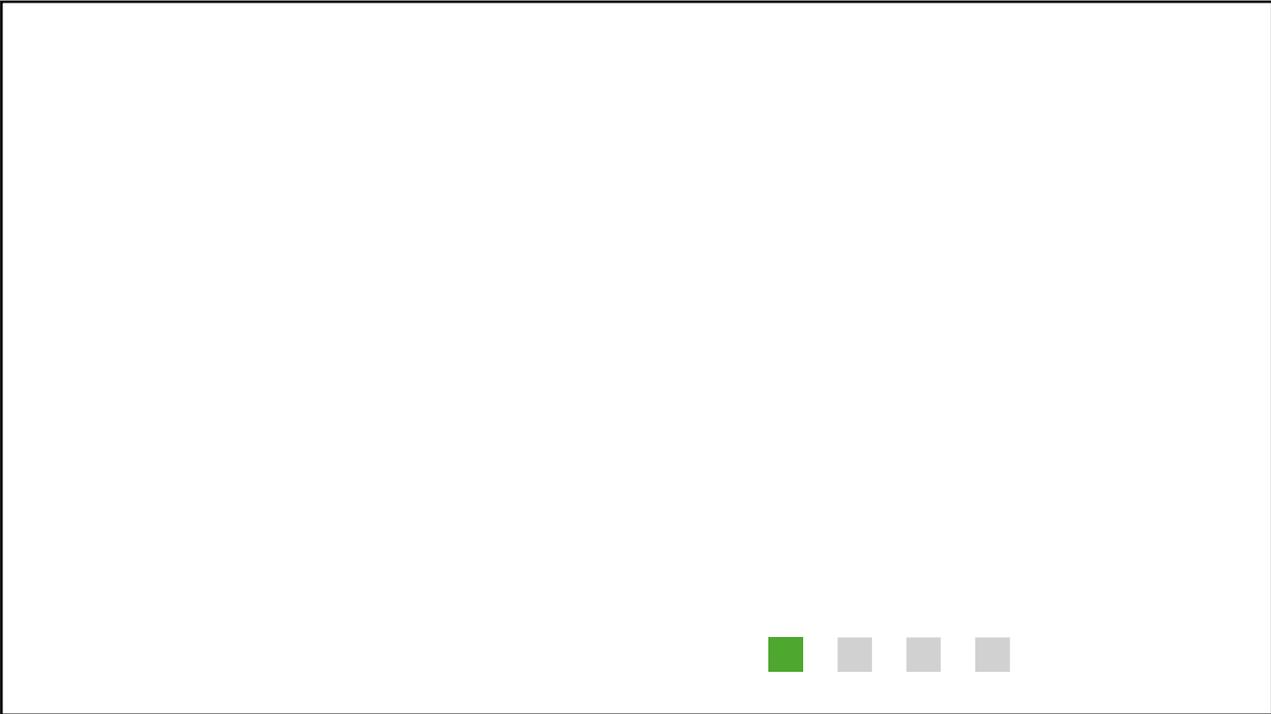
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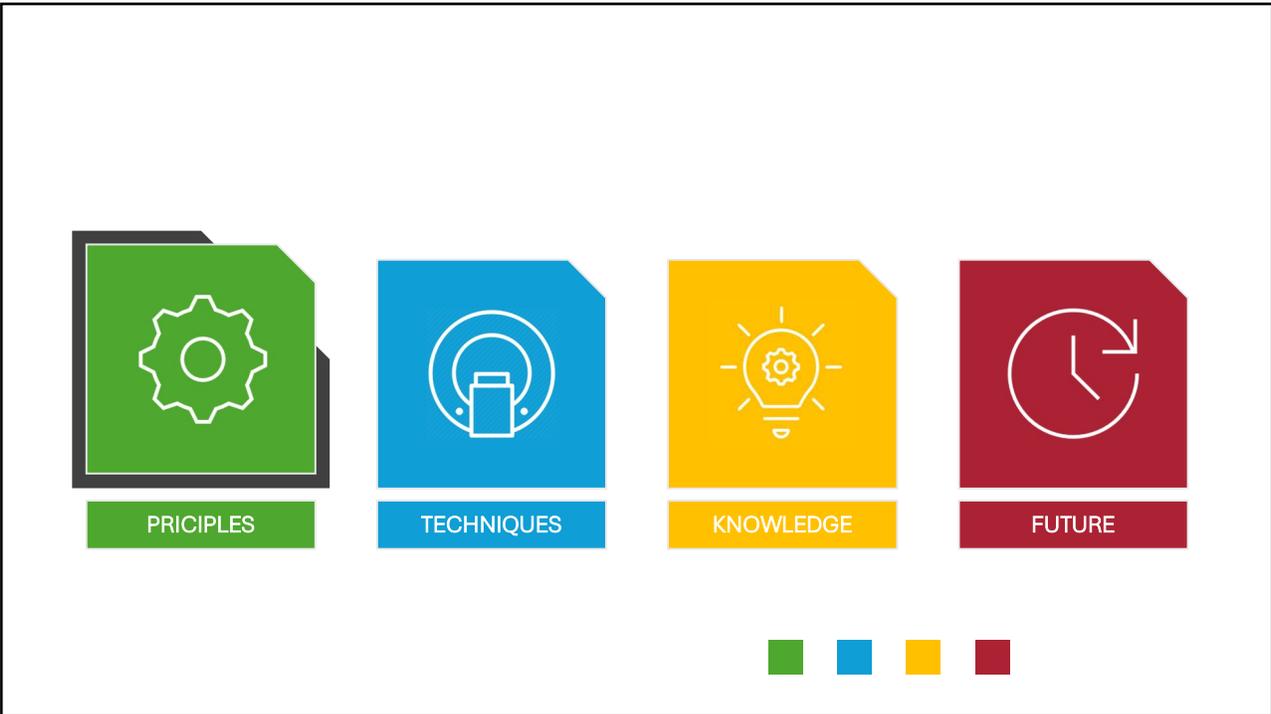


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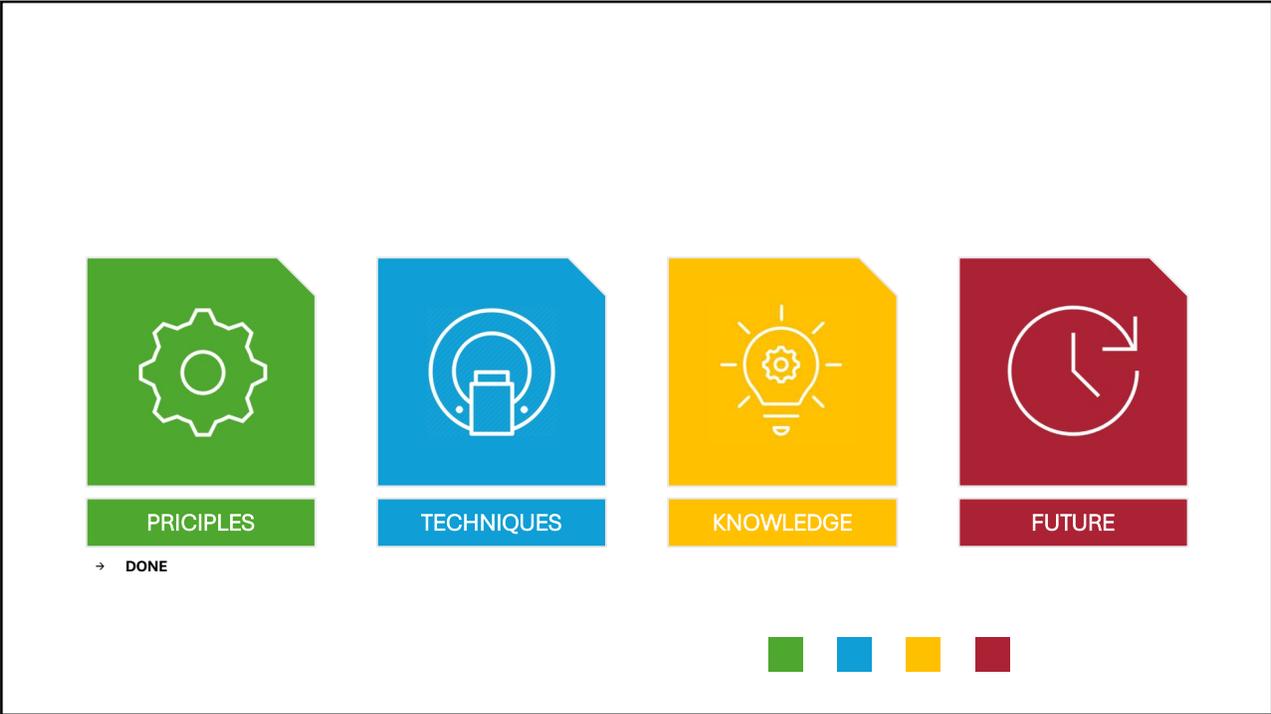
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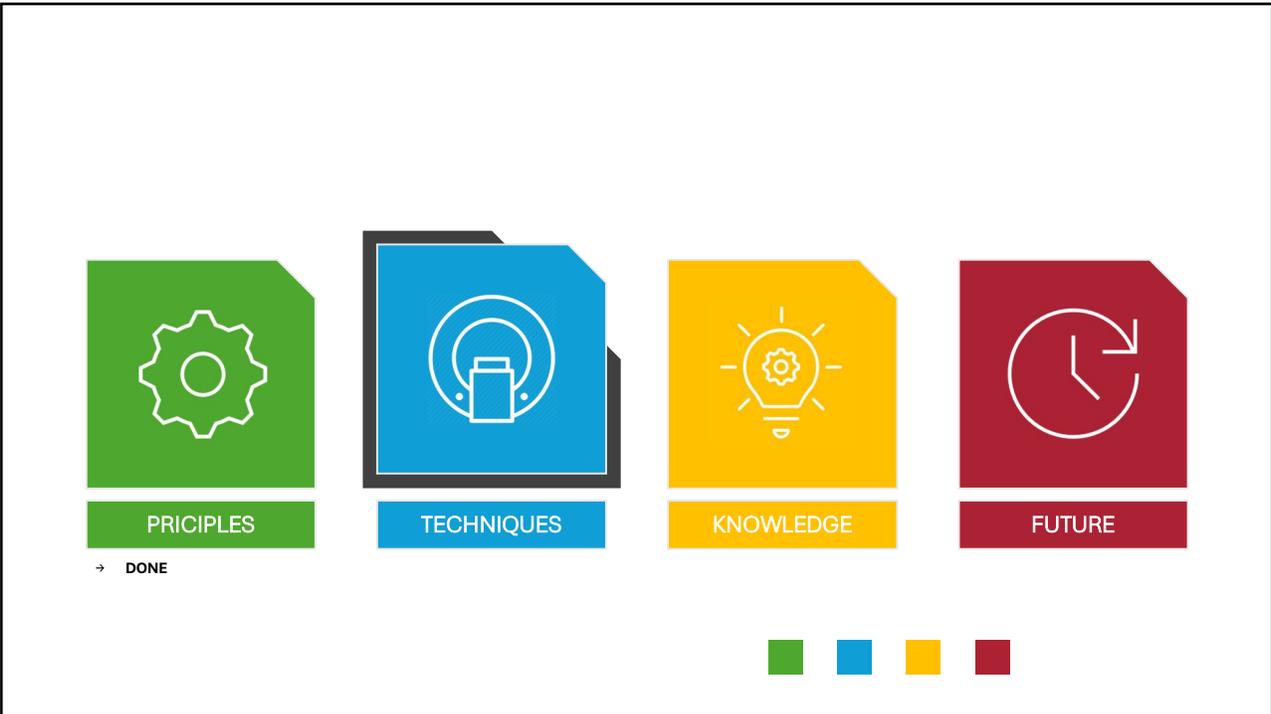
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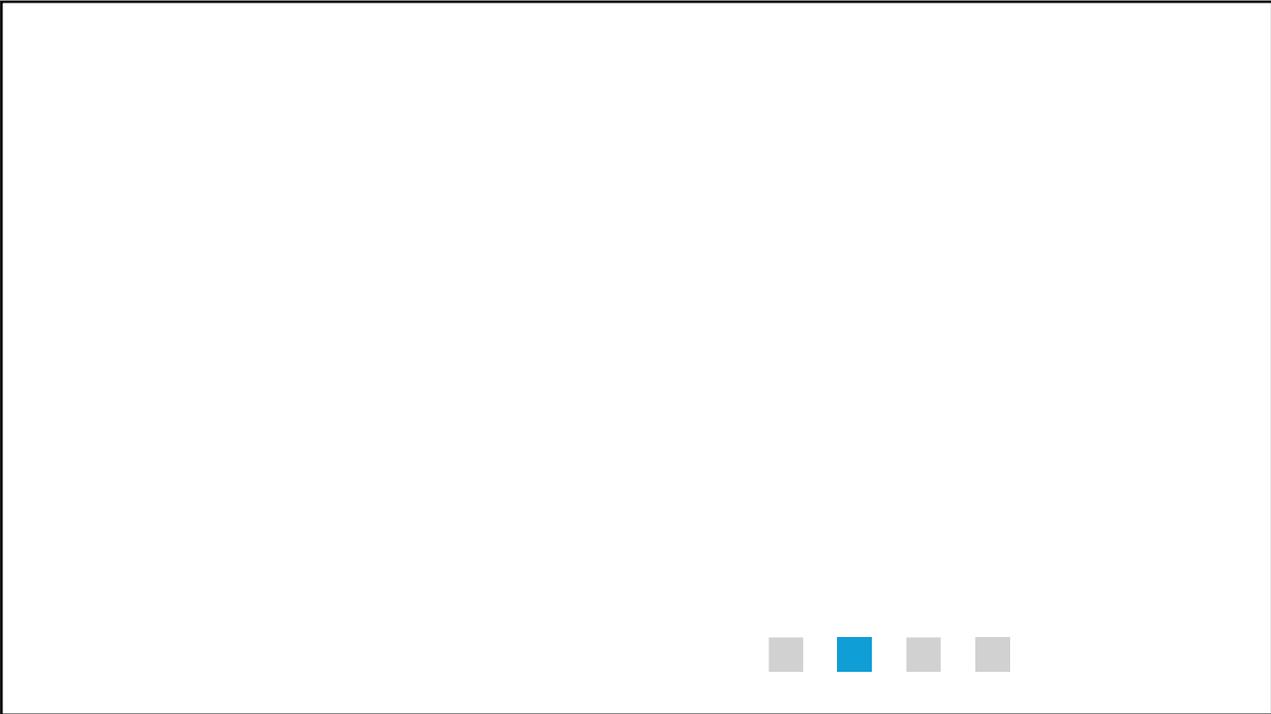
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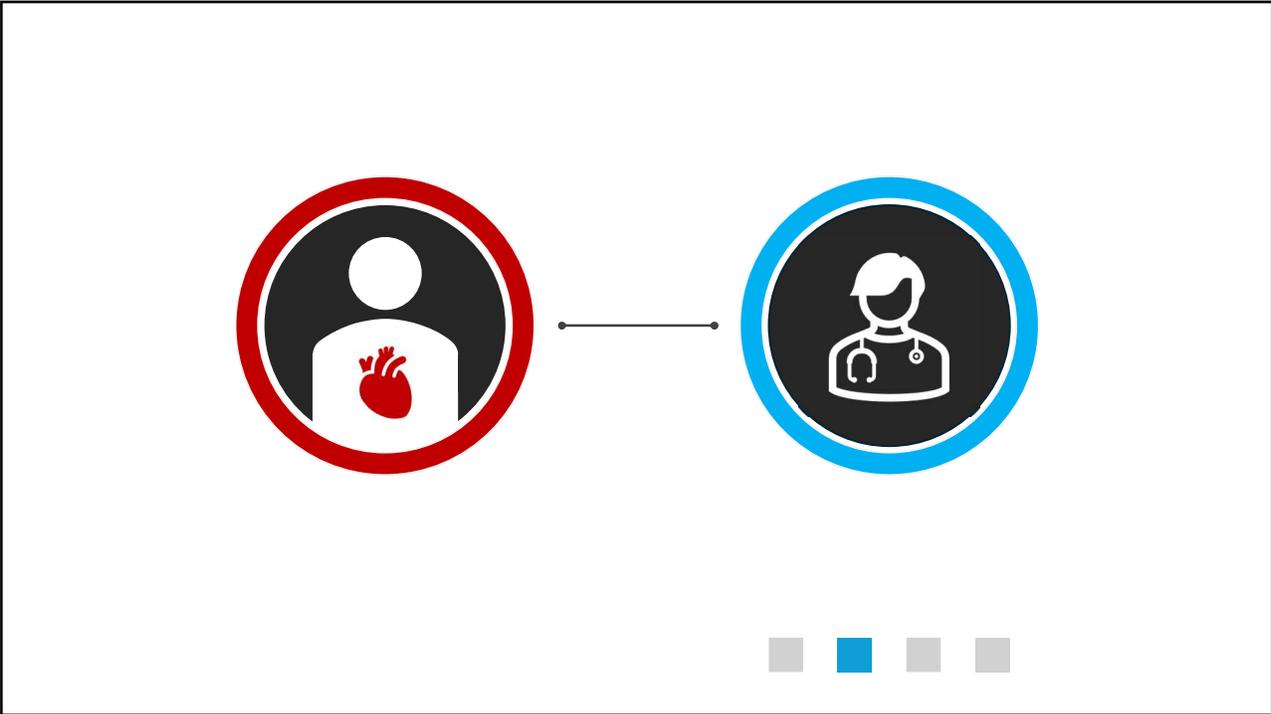
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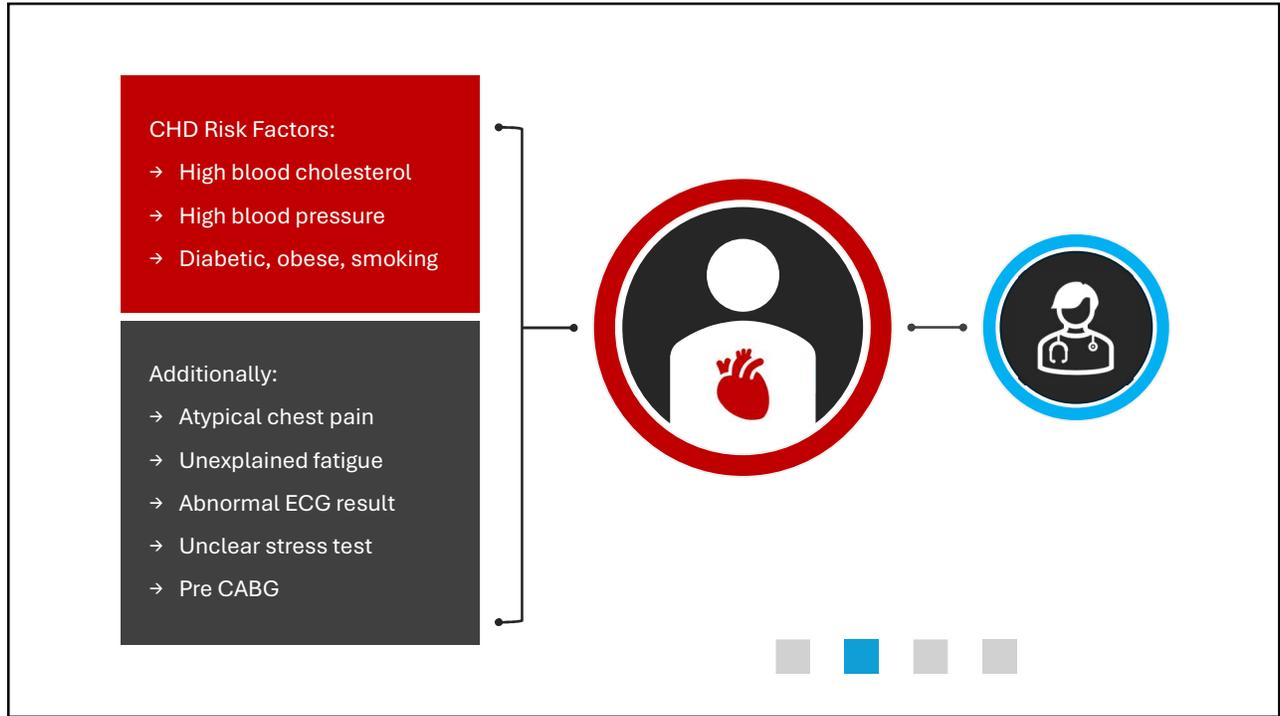
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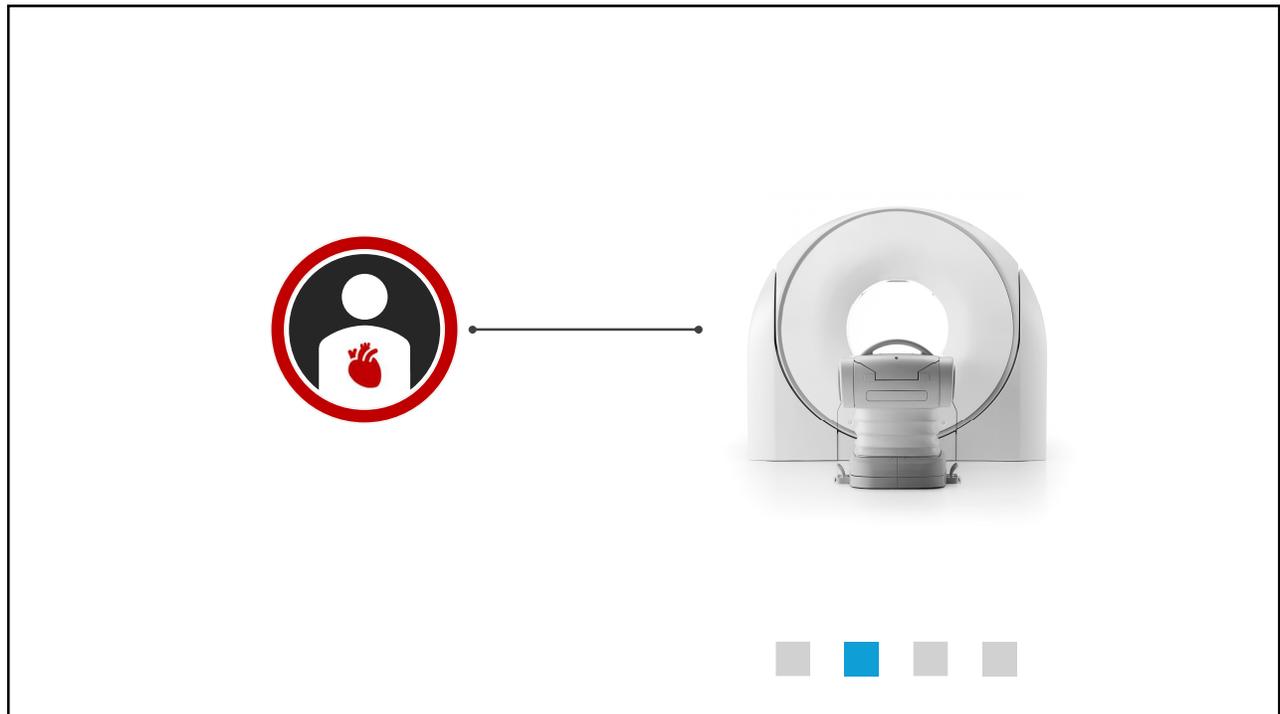
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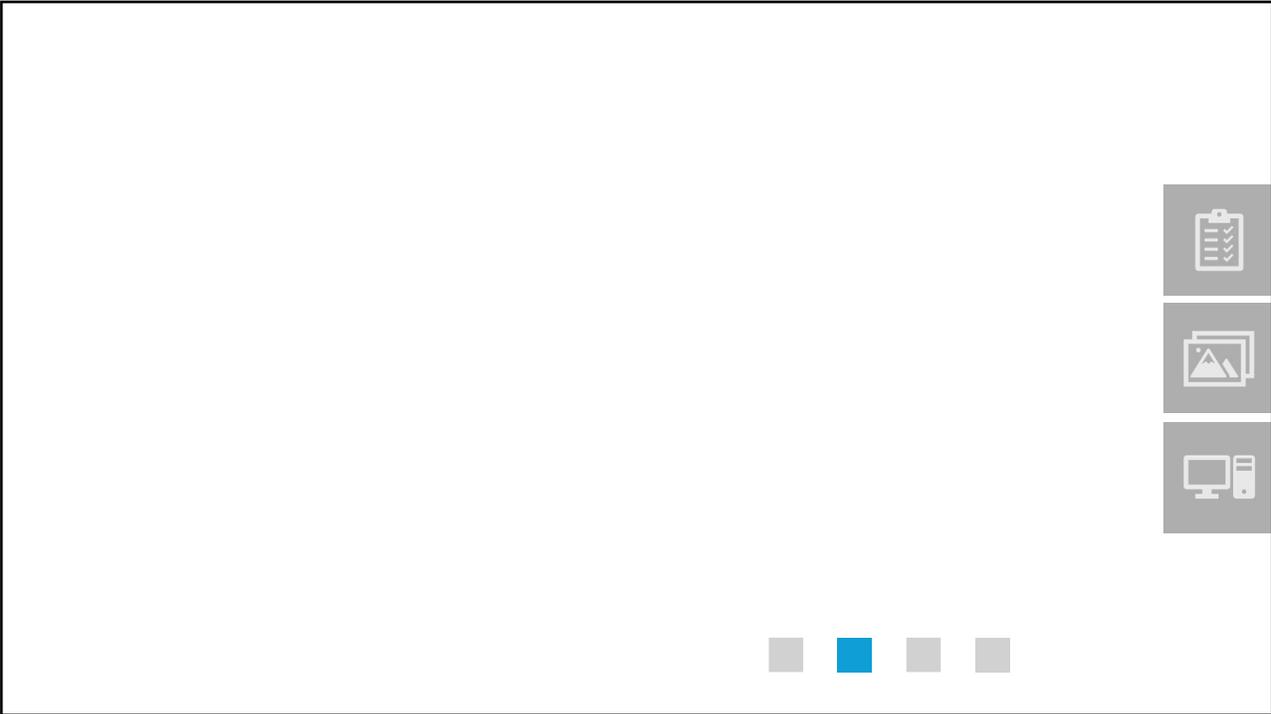


PREPARATION

SCANNING

POST PROCESSING

75



76

STEP 1. PREPARATION

PRE-APPOINTMENT

- IV Contrast preparation (RFT, eGFR, allergy, ...)
- Check heart rate / stability
- Check breath-hold
- No (Caffeine, exercise, energy drinks, Viagra, ...)

PRE-EXAMINATION

- Cannula, shave chest, ECG (prep with gel)
- Obtain history
- Explain procedure and breath-hold exercise



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STEP 1. PREPARATION

PRE-APPOINTMENT

- IV Contrast preparation (RFT, eGFR, allergy, ...)
- Check heart rate / stability

Drug Regimen for Heart Rate Controlling Medication	
Heart Rate	Dosage
<65 bpm	No Medication
66 to 79 bpm	Regime A: Tablet metoprolol (50mg) <ul style="list-style-type: none"> ▪ 50mg tablet (night before appointment) ▪ 50mg tablet (morning of appointment)
>80 bpm	Regime B: Tablet Ivabradine (5mg) <ul style="list-style-type: none"> ▪ Day 1: tab. 5mg – tab. 5mg ▪ Day 2: tab. 7.5mg – tab. 7.5mg ▪ Day 3 (appointment day): tab. 5mg & tablet metoprolol 25mg on morning of appointment.

- Cannula, shave chest, ECG (prep with gel)
- Obtain history
- Explain procedure and breath-hold exercise



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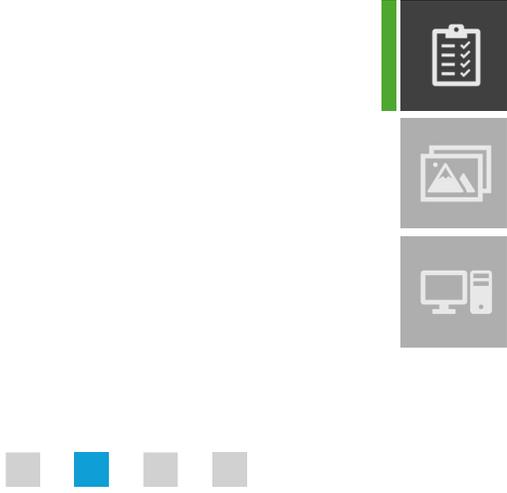
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- Check breath-hold
- No (Caffeine, exercise, energy drinks, Viagra, ...)

PRE-EXAMINATION

- Cannula, shave chest, ECG (prep with gel)
- Obtain history
- Explain procedure and breath-hold exercise



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STEP 1. PREPARATION

ECG LEAD PLACEMENT

- Leads should be placed while the arms are raised
- Leads should be placed over bone



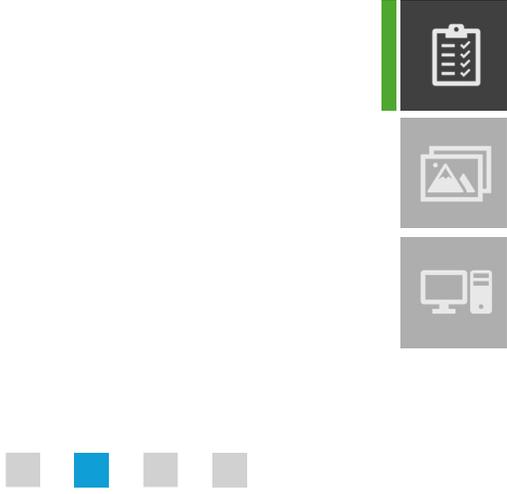
standard



alternate

ECG SIGNAL

- Low impedance, high R-waves, and no artifacts



80

STEP 1. PREPARATION

ECG SIGNAL

- Low impedance, high R-waves, and no artifacts
- Reposition leads if necessary
- DO NOT proceed with a less-than-optimal signal

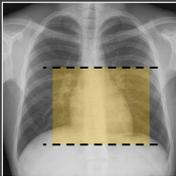
81

STEP 2. SCANNING

LOCALIZER

- Scanogram (Scout) or 3D Landmark

PRE-CONTRAST / CALCIUM SCORE




- Proceed to CCTA if calcium score < 400 (Agatston)

82

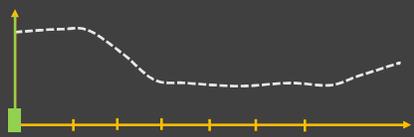
STEP 2. SCANNING

GTN (Glyceryl Trinitrate)

→ Give GTN sublingual tablet – allow 7 minutes min.

POST-CONTRAST / CCTA

→ Breath-hold exercise and determine appropriate instruction-to-scan delay.



→ Set the injector for 80-90cc Omnipaque @ 5cc/s



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STEP 2. SCANNING

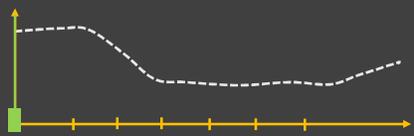
GTN (Glyceryl Trinitrate)

→ Give GTN sublingual tablet – allow 7 minutes min.

- Coronary vasodilation
- Prevents coronary spasm

POST-CONTRAST / CCTA

→ Breath-hold exercise and determine appropriate instruction-to-scan delay.



→ Set the injector for 80-90cc Omnipaque @ 5cc/s



84

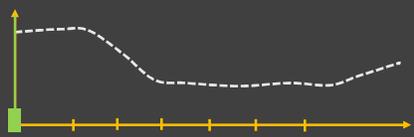
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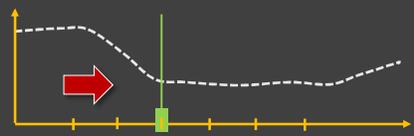
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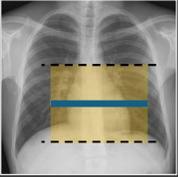
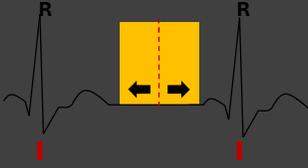
86

STEP 2. SCANNING

BOLUS TRACKING POSITION

- Should be at the center of the scanned area.
- Place trigger ROI on Aorta

COVERAGE AND GATING MODE

→ Use extended prospective gating (HR below 80bpm)







87

STEP 3. POST PROCESSING

MULTI-PHASE RECONSTRUCTION

→ Reconstruct available cardiac phase range with PIQE-CARDIAC kernel (1024 matrix) at 5% intervals



VESSEL ANALYSIS







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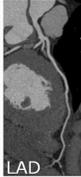
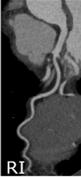
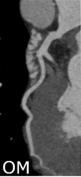
STEP 3. POST PROCESSING

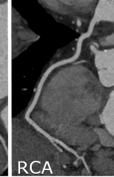
MULTI-PHASE RECONSTRUCTION

→ Reconstruct available cardiac phase range with PIQE-CARDIAC kernel (1024 matrix) at 5% intervals

VESSEL ANALYSIS

→ Send reconstructions to VITREA for analysis









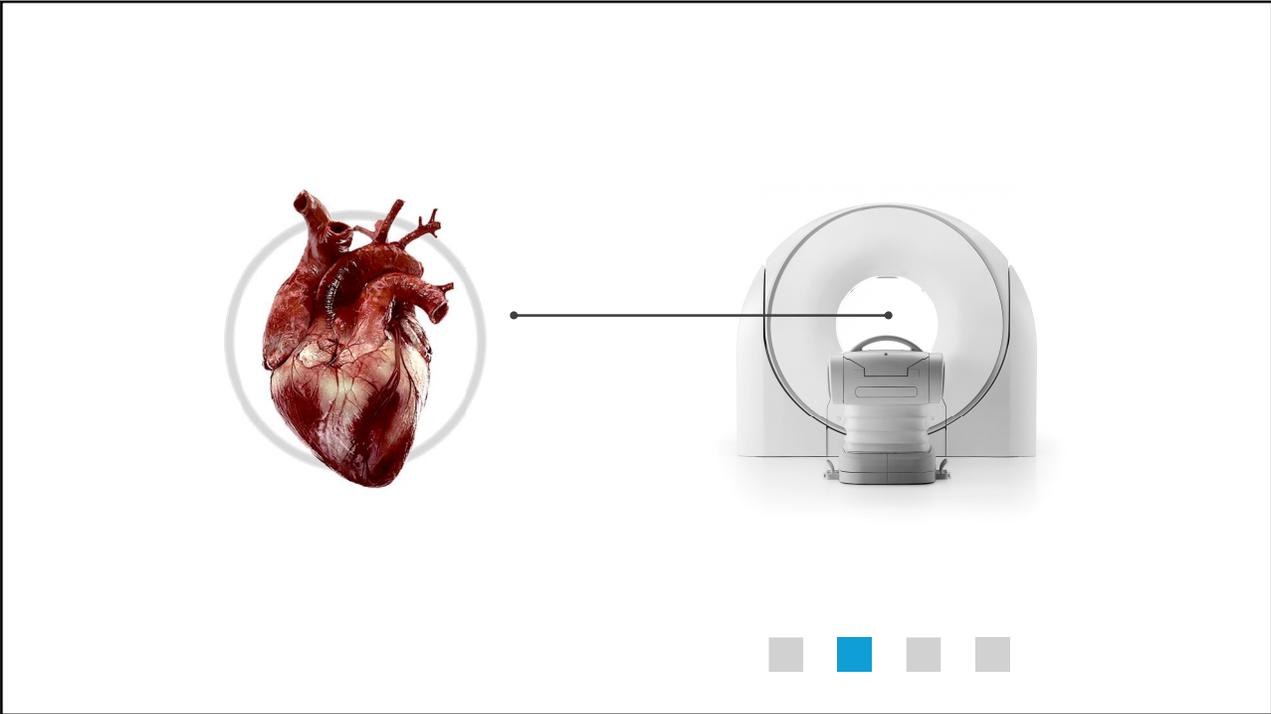
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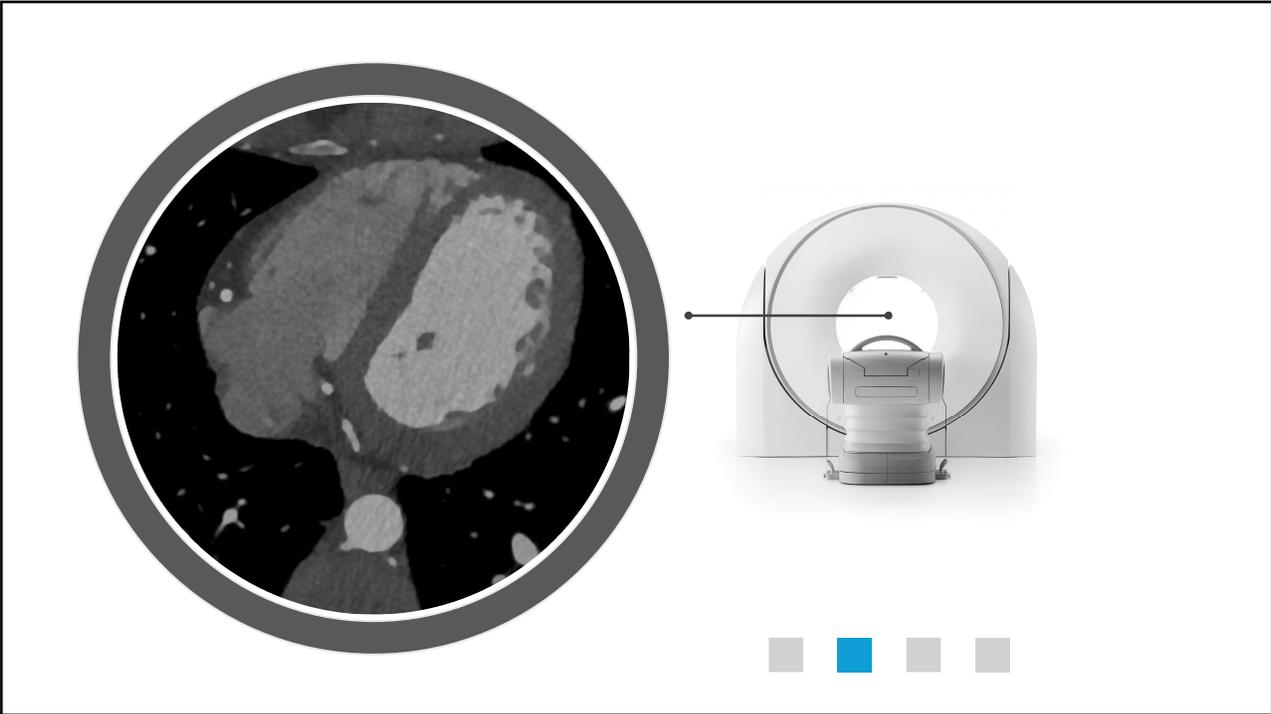




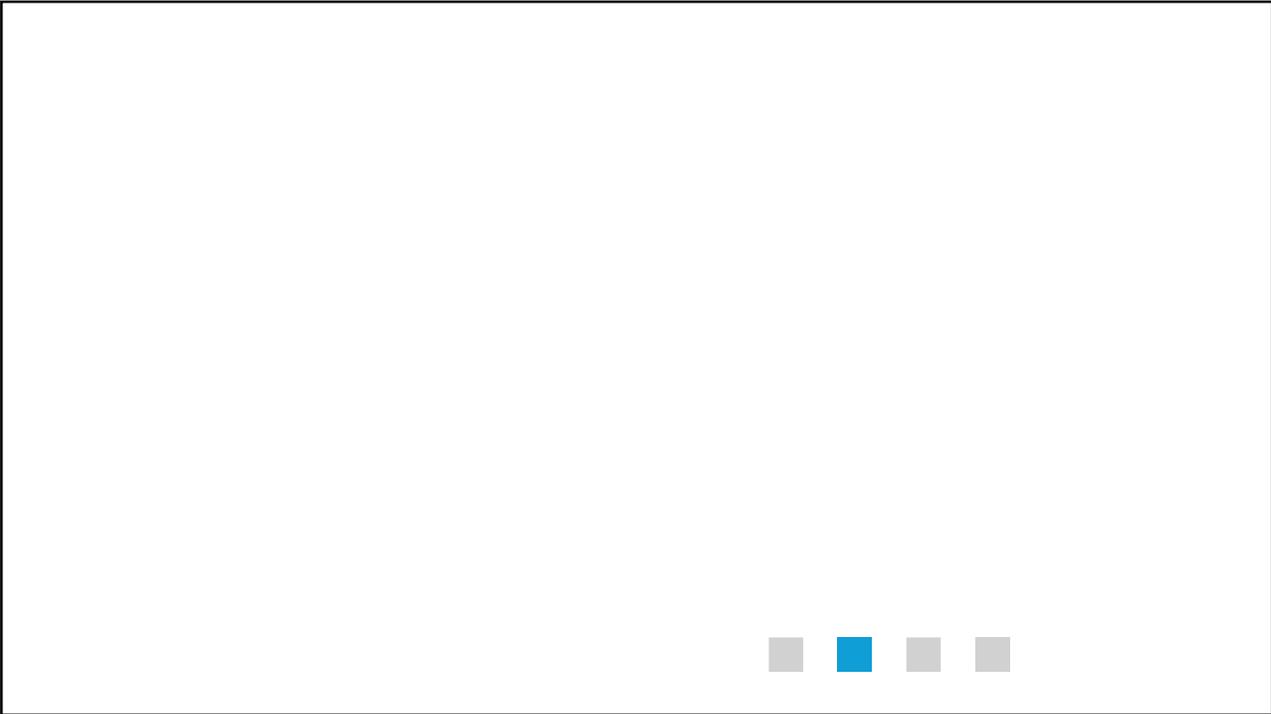
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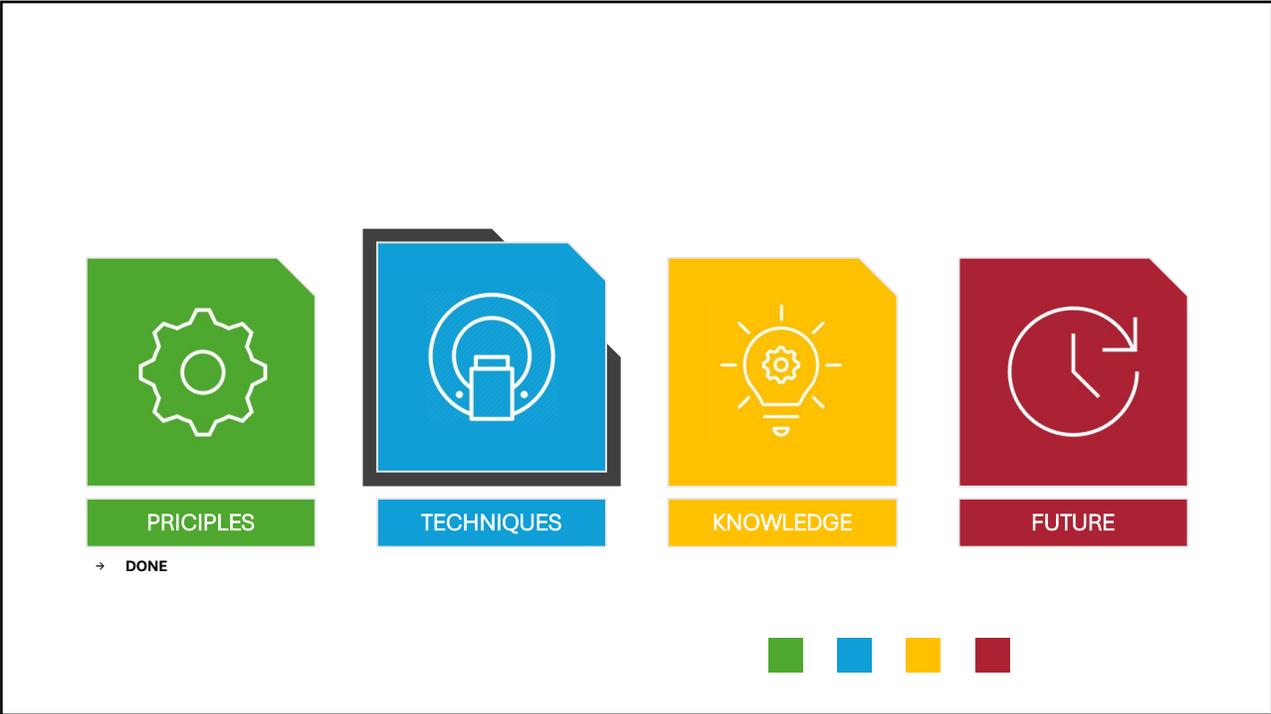
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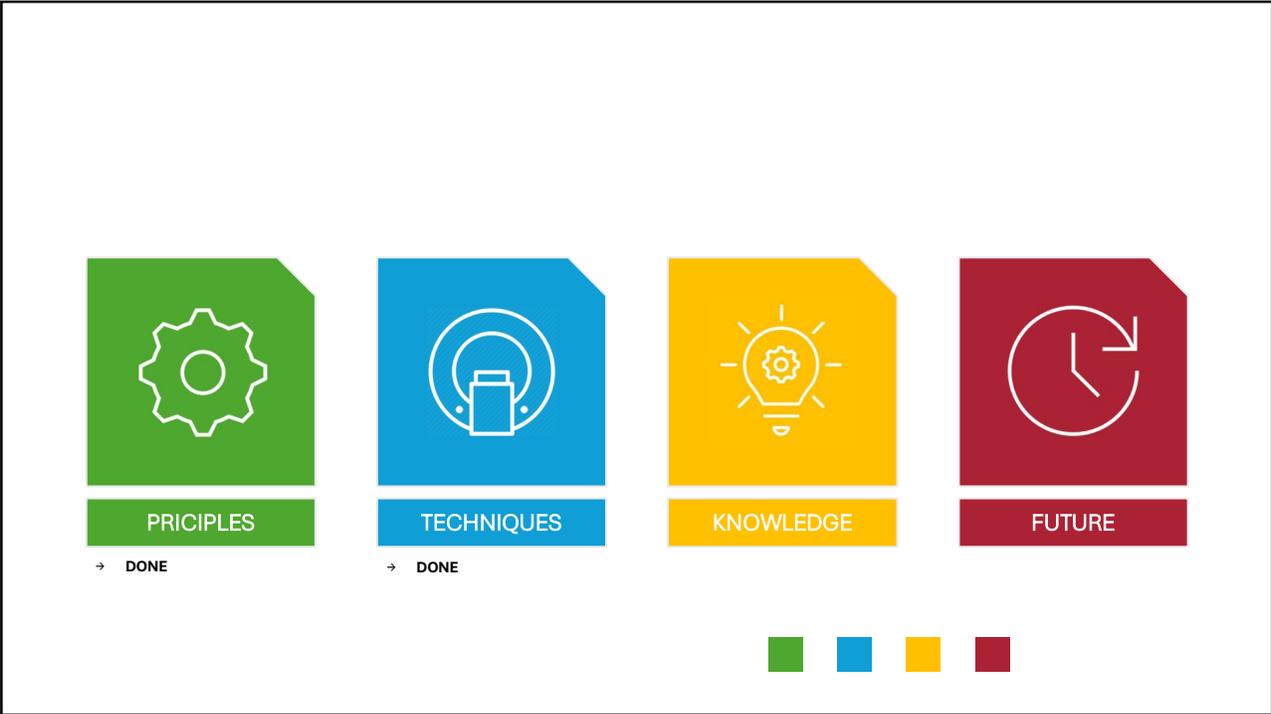
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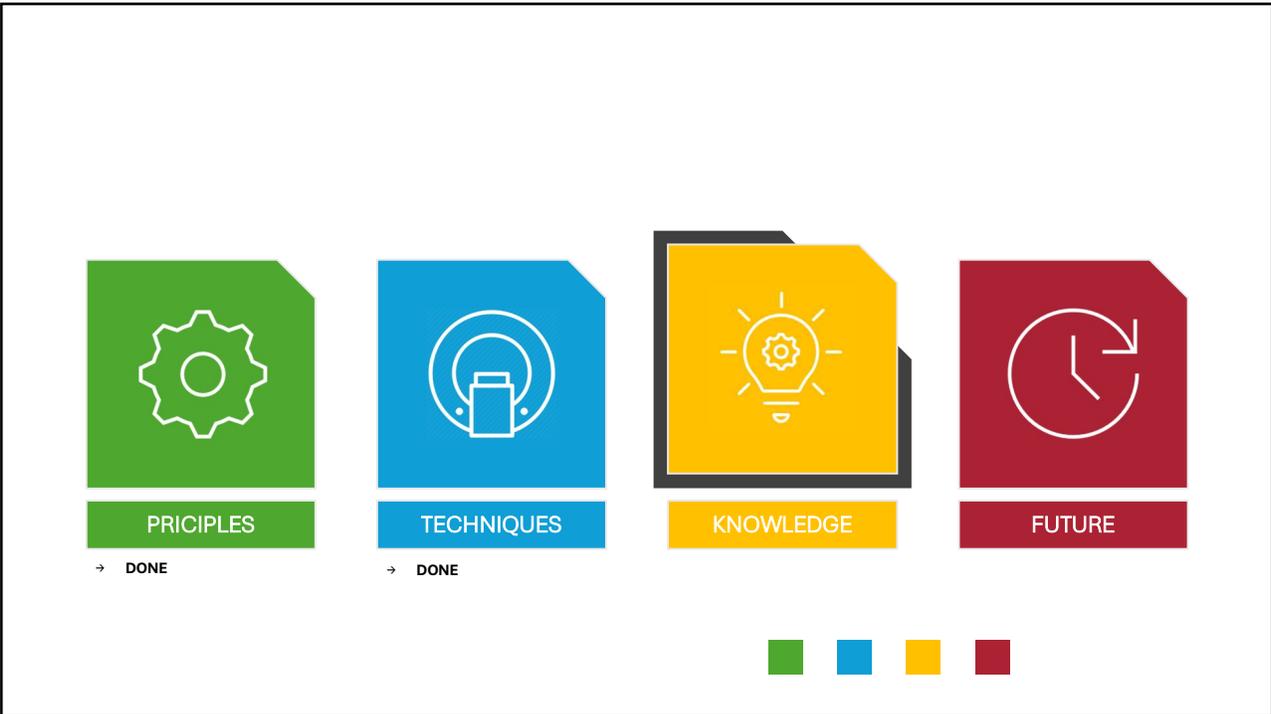
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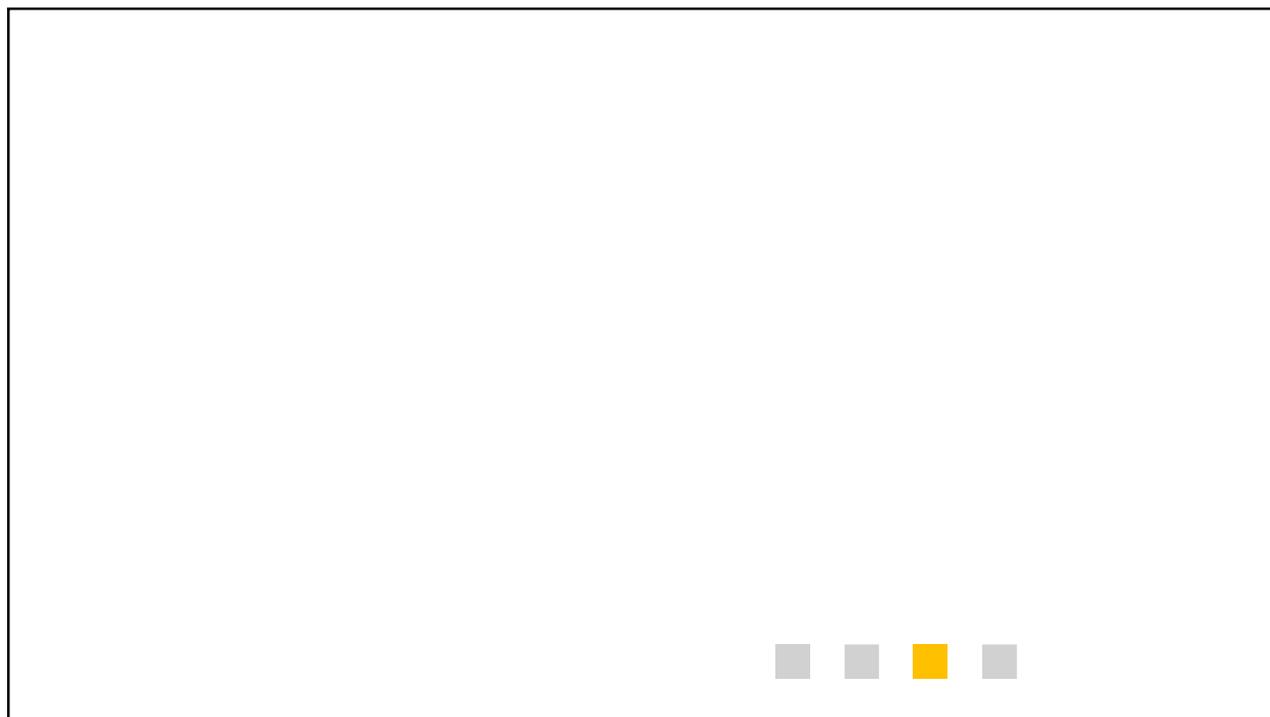
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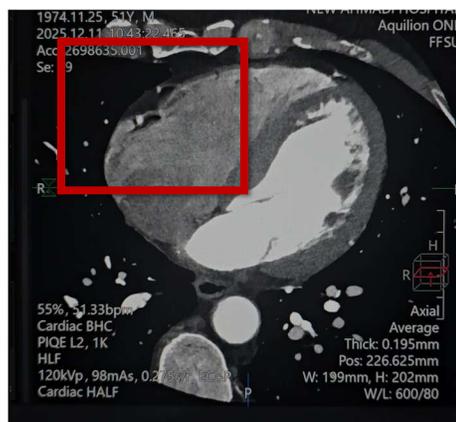


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CORONARY. MOTION

The Right Coronary Artery (RCA) is consistently considered the most challenging vessel to image clearly on Cardiac CT Angiography (CCTA) due to its unique anatomical position and movement (vessel displacement range 5-20mm)

Let us look at some scientific evidence ...



98

CORONARY. MOTION

The Right Coronary Artery (RCA) is consistently considered the most challenging vessel to image clearly on Cardiac CT Angiography (CCTA) due to its unique anatomical position and movement (vessel displacement range 5-20mm)

Let us look at some scientific evidence ...

Purpose:

To characterize the three-dimensional motion of the coronary arteries along the entire vessel length and to identify the temporal location and duration of periods of relatively low cardiac motion in patients with coronary artery disease.



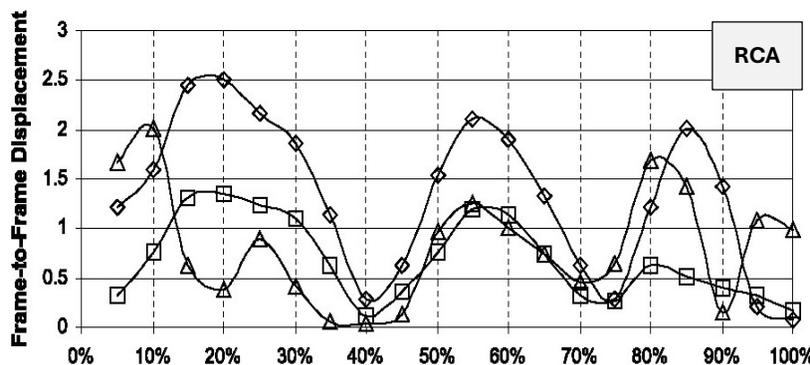
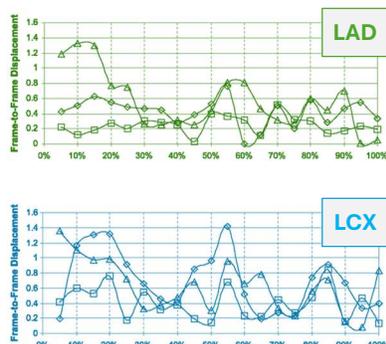
Johnson et al., 2004



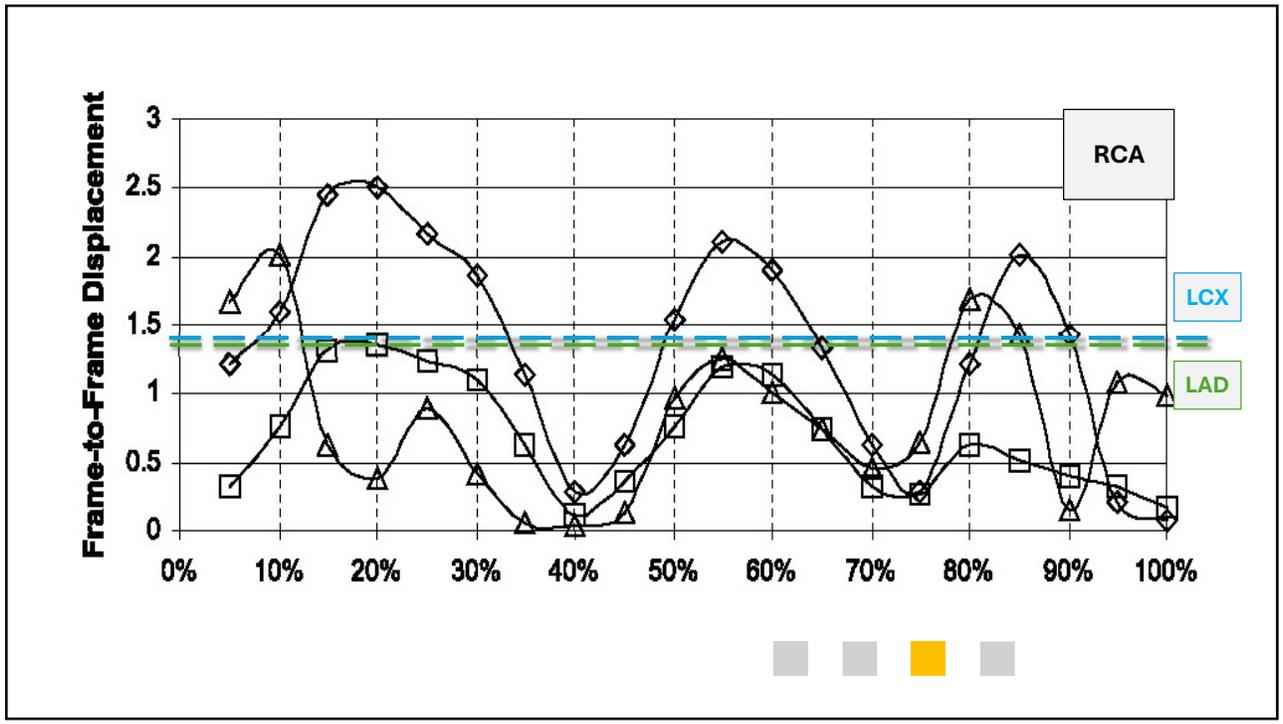
99

Frame-to-Frame Displacement of Mid-Segment:

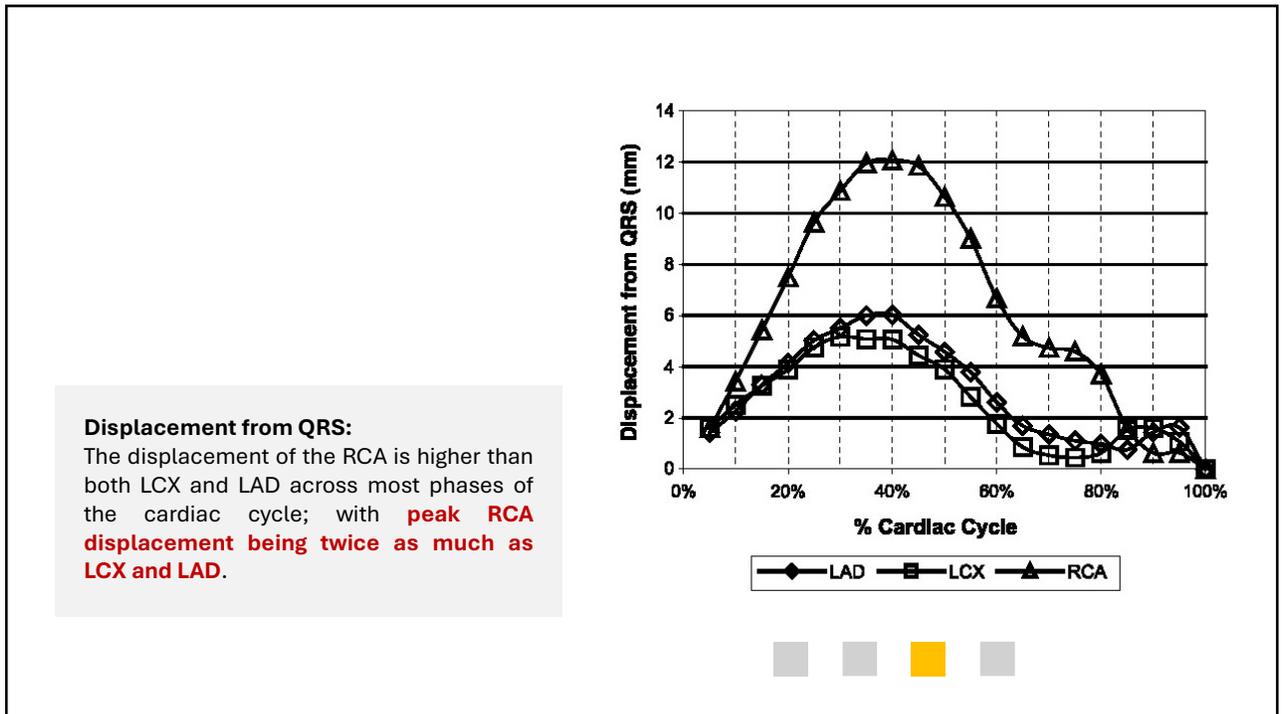
Motion of the **LAD** and **LCX** is predominantly in the **cranial-caudal direction (▲)** while motion of the **RCA** is predominantly in the **right-left direction (◆)**. Average RCA frame-to-frame displacement is more than twice that of LAD and LCX across all phases of cardiac cycle (check scale).



100



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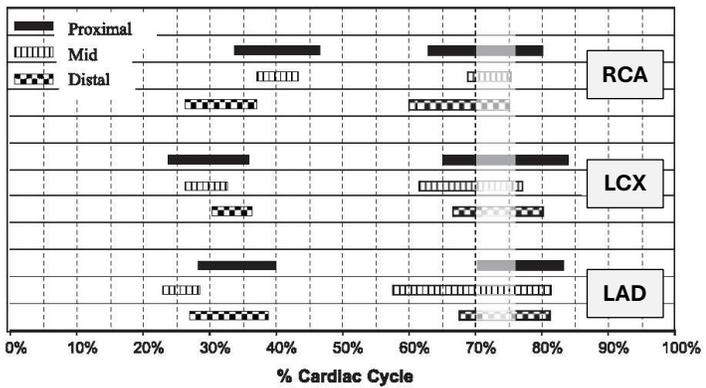


Displacement from QRS:
 The displacement of the RCA is higher than both LCX and LAD across most phases of the cardiac cycle; with **peak RCA displacement being twice as much as LCX and LAD.**

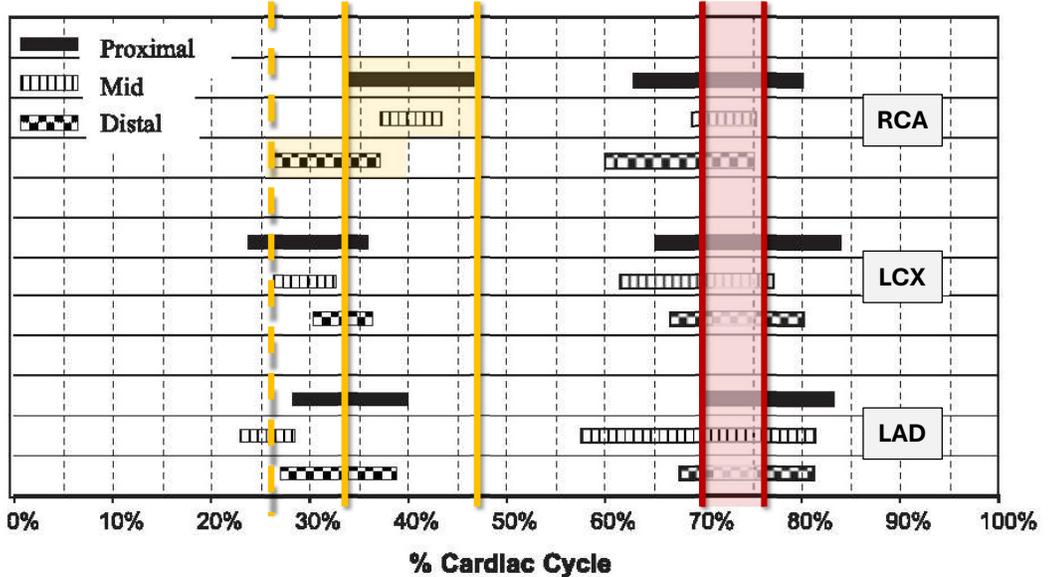
102

Low-Motion Periods:

The rest periods following ventricular systole are shorter than in diastole and occur at different times (no single time window covers all vessels). A **window of the cardiac cycle exists from 71% to 76%** after ventricular relaxation during which all segments of the three coronary arteries had on average less than 1 mm frame-to-frame displacement.



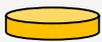
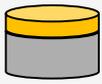
103



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RADIATION. DOSE

There are three commonly referenced dose metrics in CT imaging ...

CTDI	DLP	EFFECTIVE DOSE
		
Avg. dose of a single slice	$CTDI \times \text{Scan length}$	$DLP \times \text{Organ k-factor}$

■ ■ ■ ■

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RADIATION. DOSE

CTDI	DLP	EFFECTIVE DOSE
		
Avg. dose of a single slice	$CTDI \times \text{Scan length}$	$DLP \times \text{Organ k-factor}$
RADIATION EXPOSURE		BIOLOGICAL RISK

■ ■ ■ ■

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CTDI
Avg. dose of a single slice
The **gold standard** and **most accurate** and correct metric to reference and describe radiation dose in CT
RADIATION EXPOSURE

DLP
CTDI \times Scan length
The **gold standard** and **most accurate** and correct metric to reference and describe radiation dose in CT
RADIATION EXPOSURE

EFFECTIVE DOSE
DLP \times Organ k-factor
Scientifically incorrect dose metric for CT scans of individuals
BIOLOGICAL RISK

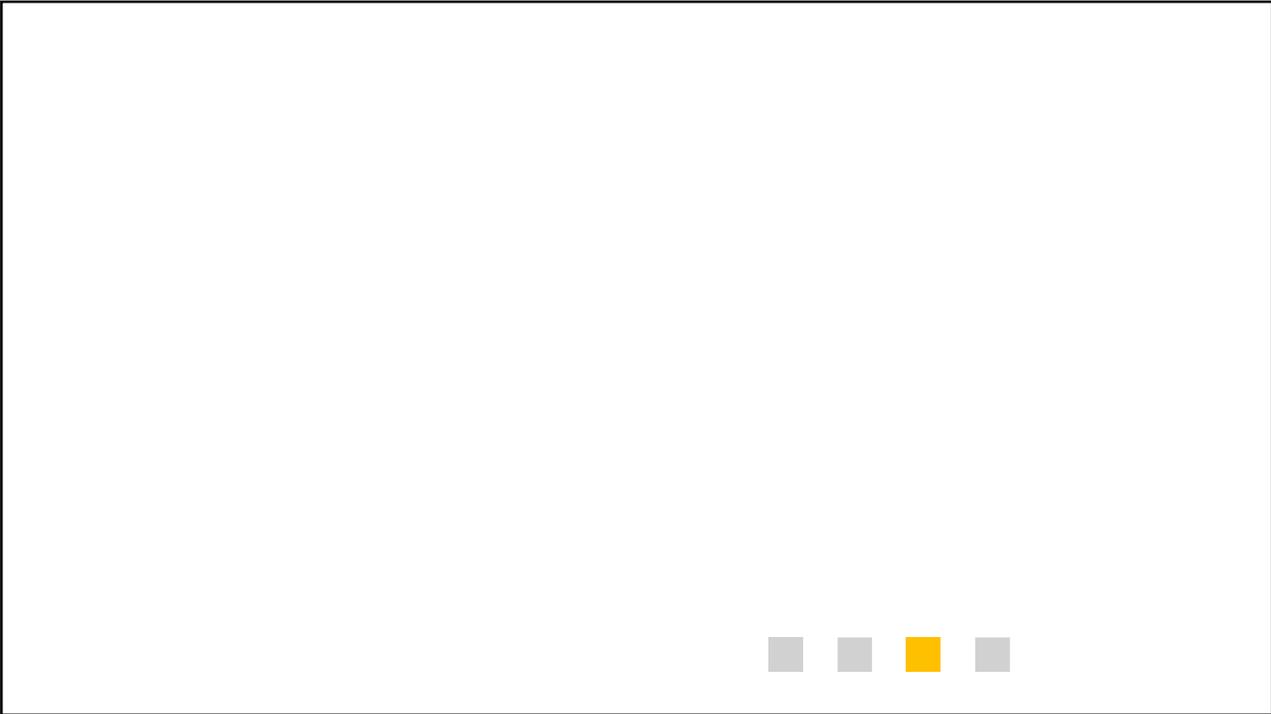
107

CTDI
Avg. dose of a single slice
The **gold standard** and **most accurate** and correct metric to reference and describe radiation dose in CT
RADIATION EXPOSURE

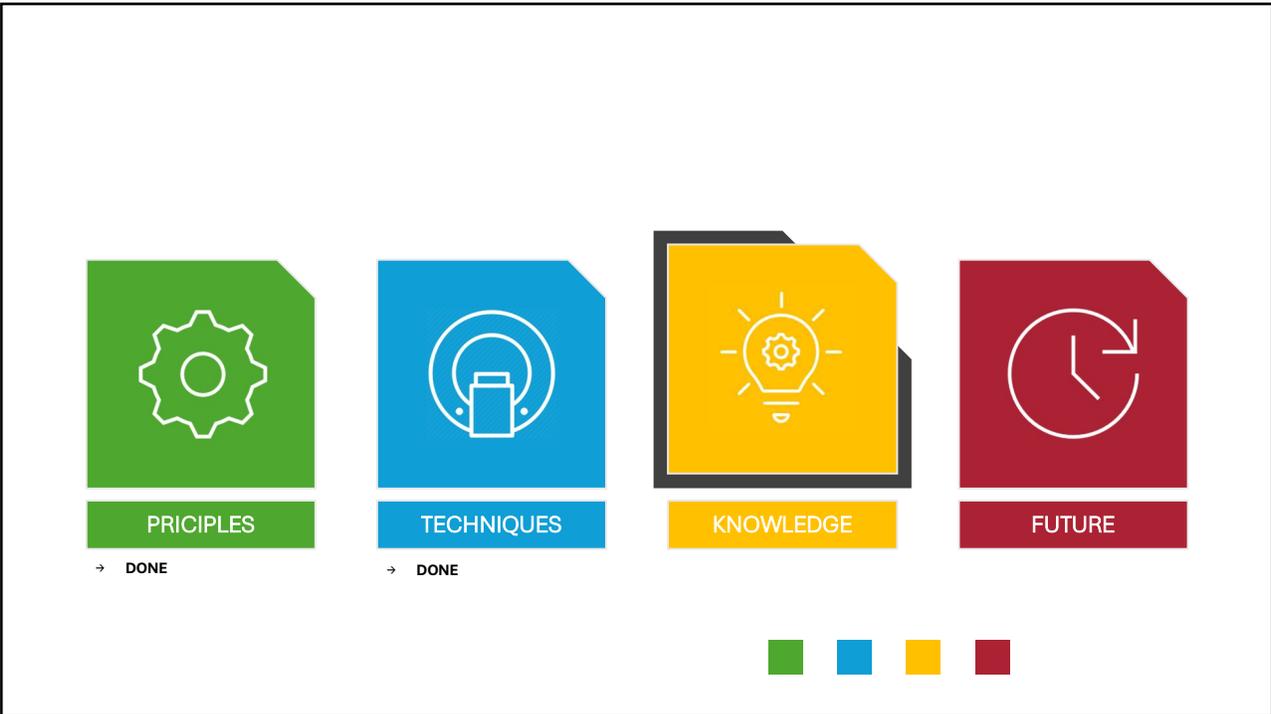
DLP
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RADIATION EXPOSURE

EFFECTIVE DOSE
DLP \times Organ k-factor
Scientifically incorrect dose metric for CT scans of individuals
BIOLOGICAL RISK

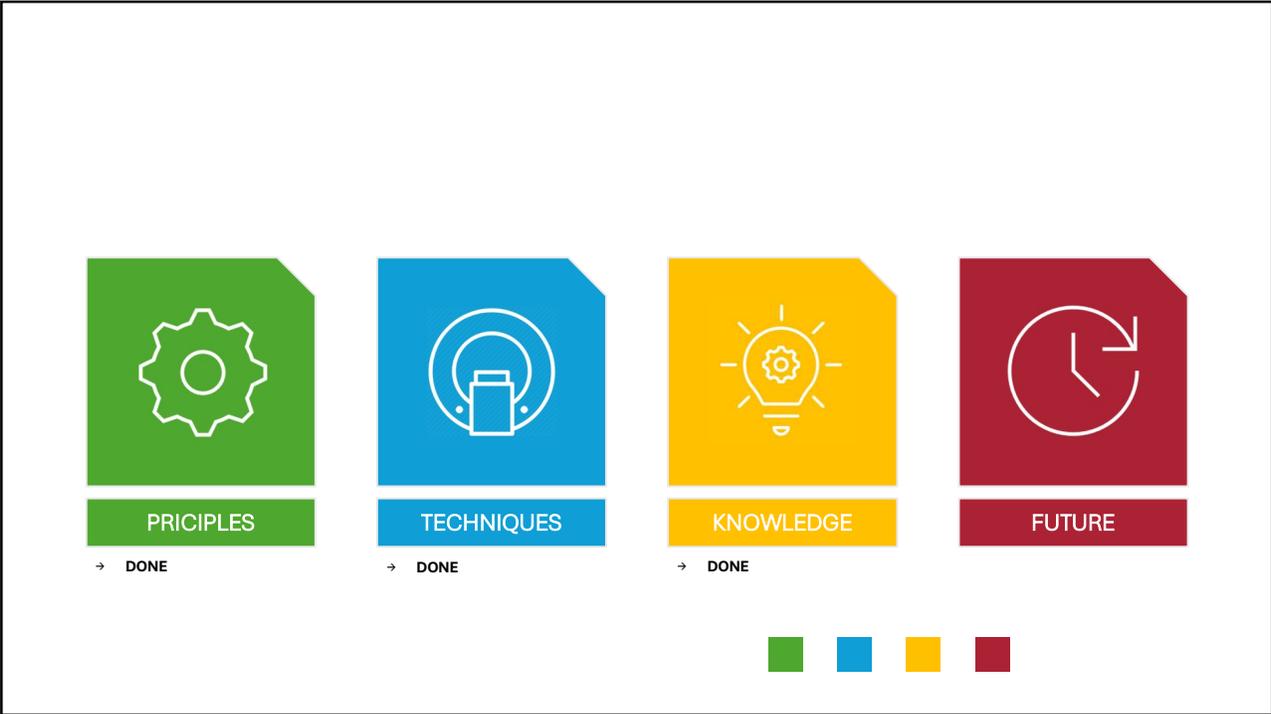
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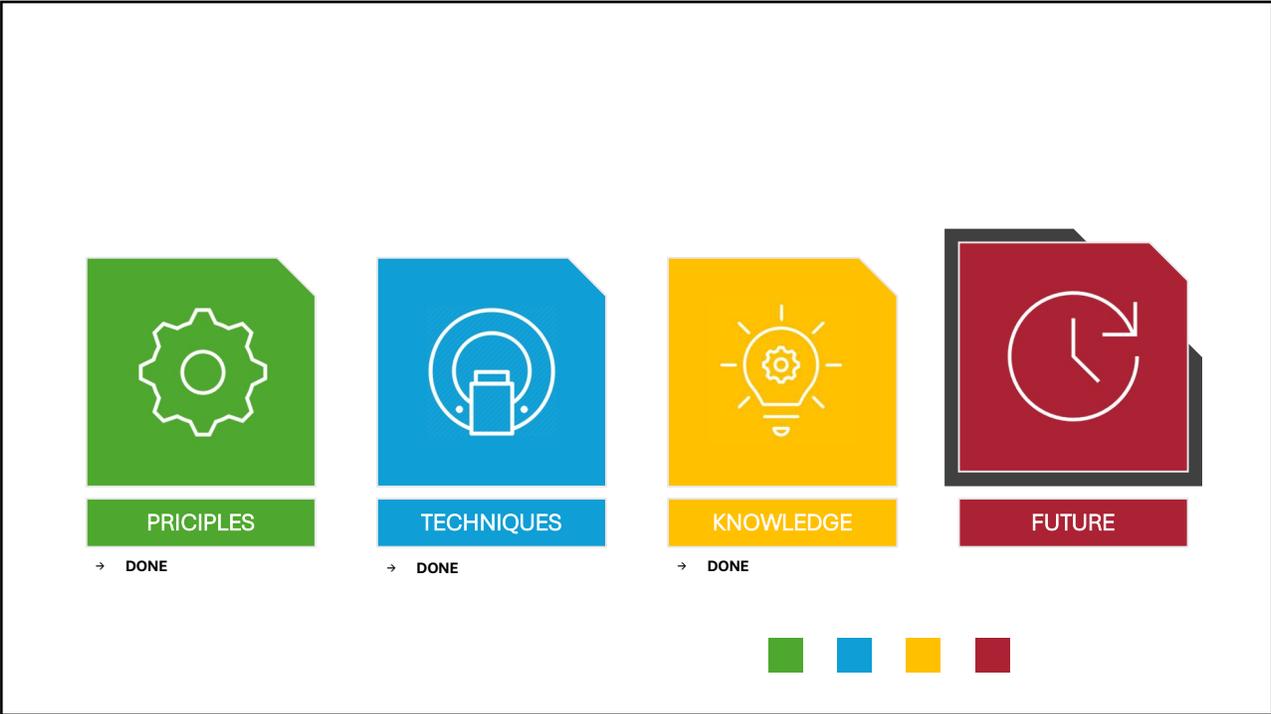
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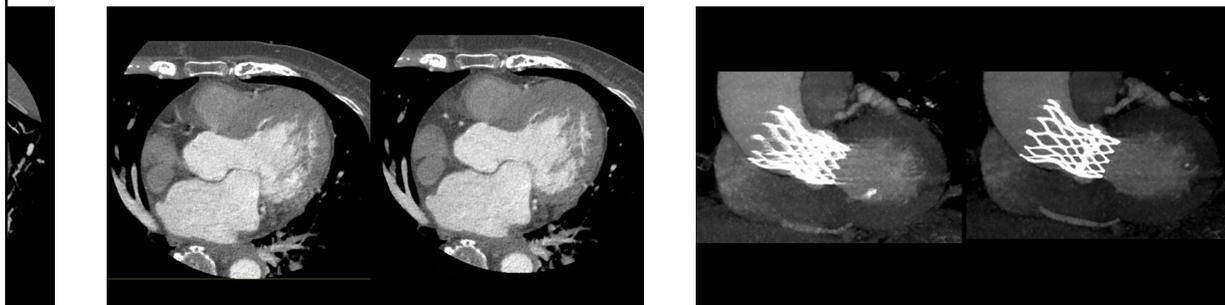
113

PROPECT 1. DL MOTION CORRECTION

DL MOTION CORRECTION

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PROPECT 1. **DL MOTION CORRECTION**



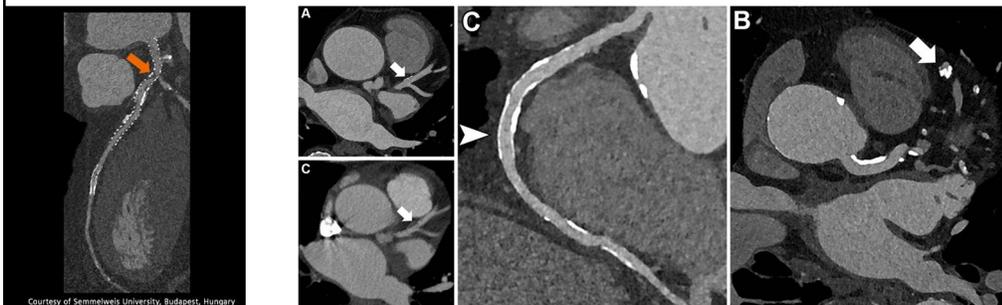
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PROPECT 2. **PHOTON COUNTING**



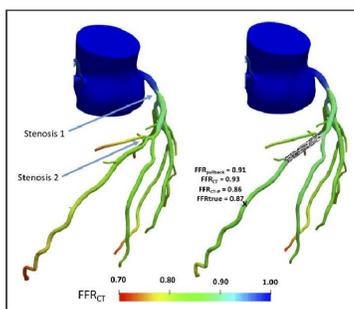
116

PROPECT 2. PHOTON COUNTING



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PROPECT 3. FRACTIONAL FLOW RESERVE_{CT}



Computational fluid dynamics analysis where a color map is overlaid onto the coronary CT image:

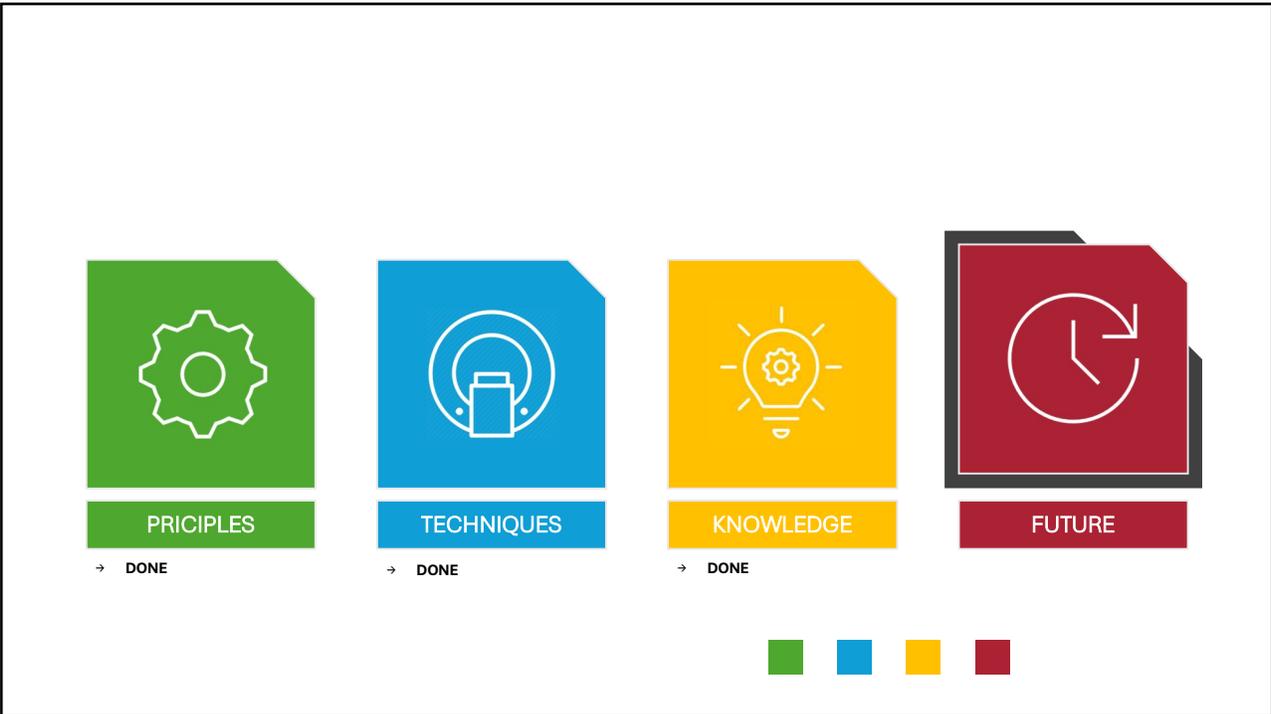
- **Green/Blue:** Indicates normal blood flow (FFR >0.80, typically)
- **Yellow/Red:** Indicates a significant pressure drop across the stenosis (FFR ≤0.80) - **confirming a hemodynamically significant blockage** that may require intervention.



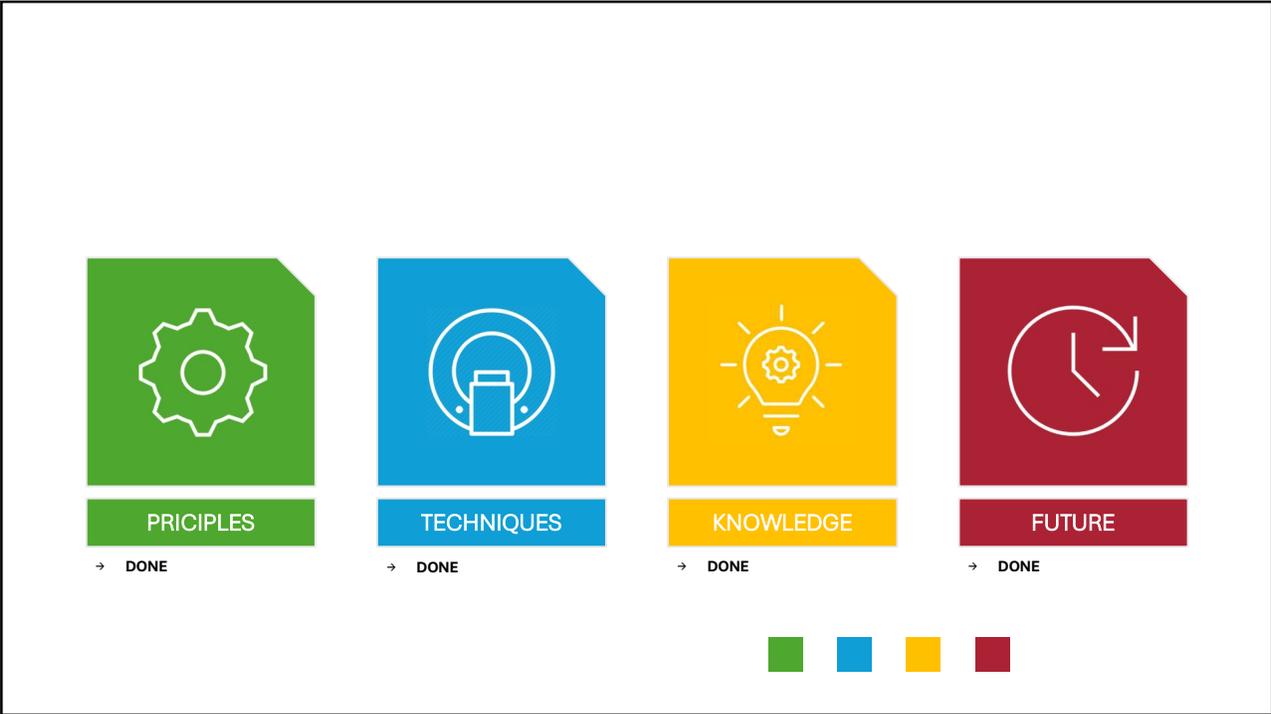
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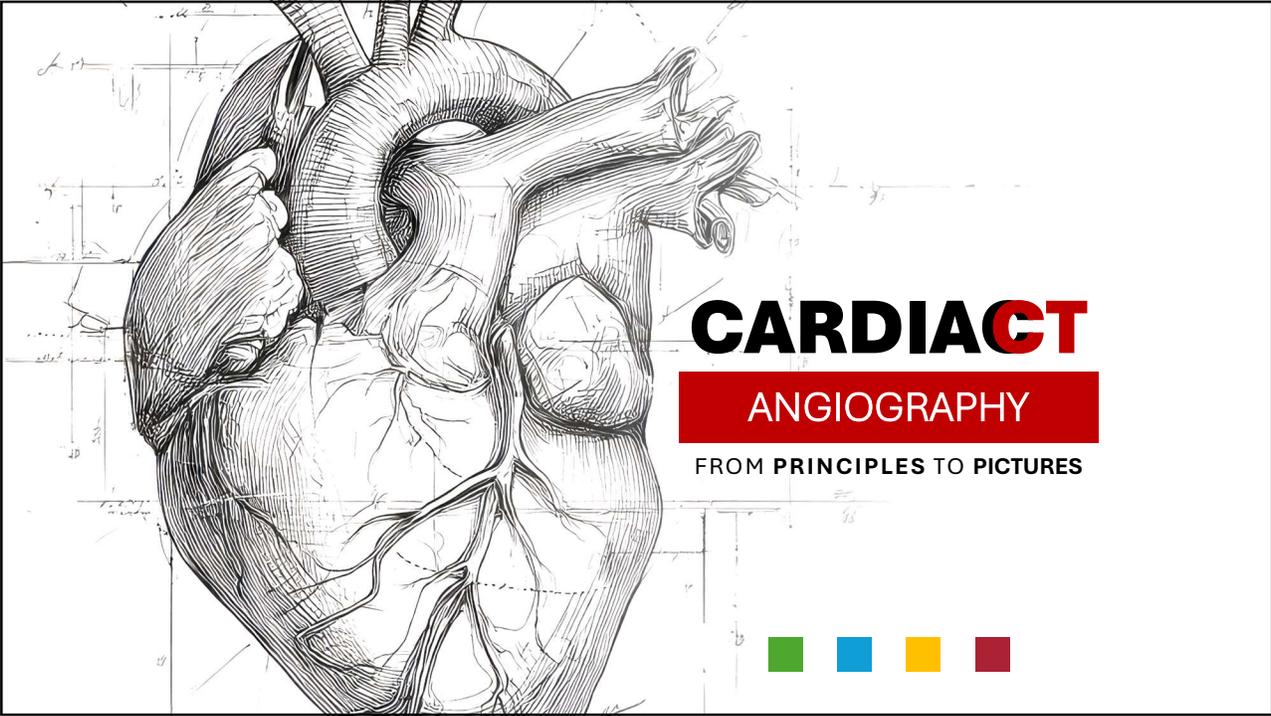
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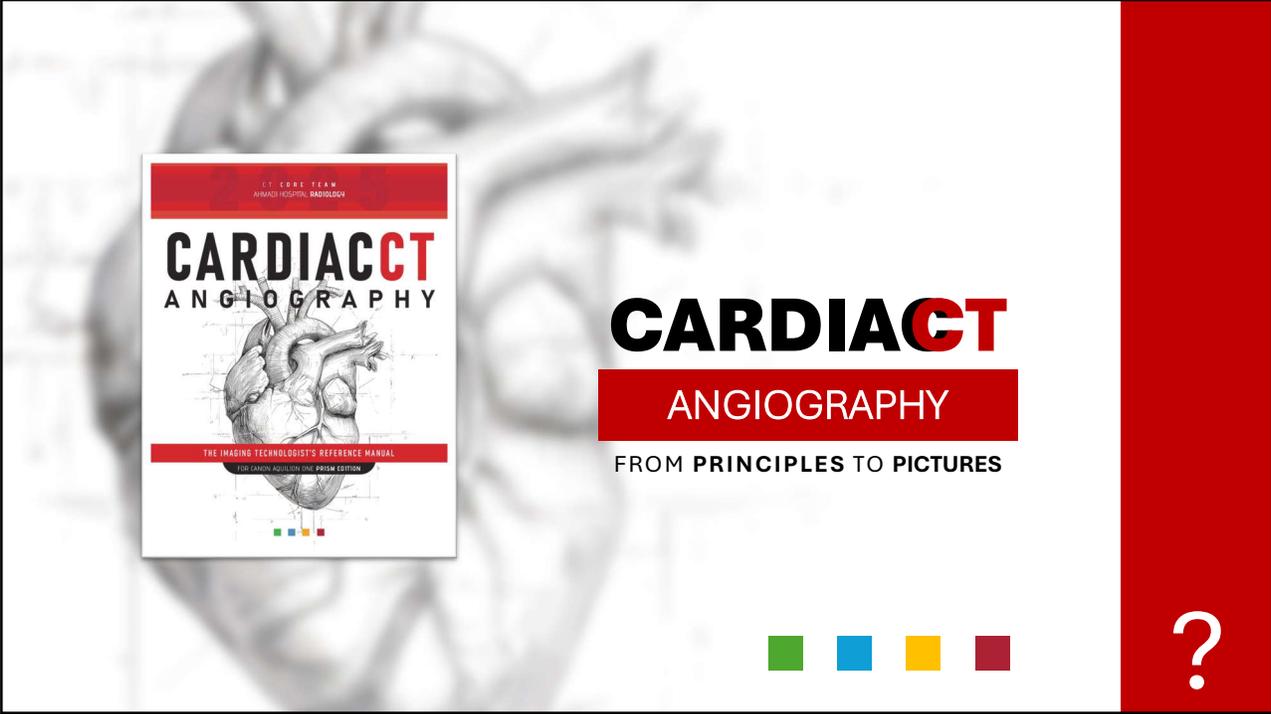
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