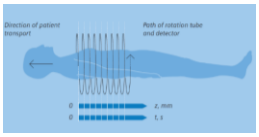
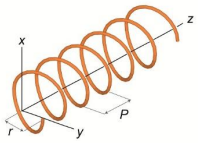


# The Thing About "PITCH!"

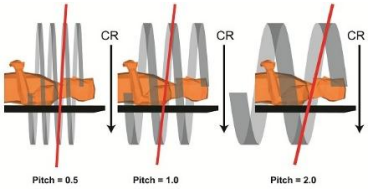



Mike Enriquez, MPA, BSRT(R)(CT)
President, RMP, Inc.
2015

**MDCT = MSCT and SDCT = SSCT**

## "PITCH" Terminology

- "BEAM" Pitch
  - MDCT term used by Siemens, Toshiba & Marconi
- "SLICE" Pitch
  - MDCT term used by General Electric
  - Used by me to express the "angle" of the slice relative to the vertical CR
- "DETECTOR" Pitch
  - SDCT term




2

## What is "PITCH?"

- "PITCH"
  - **A factor, mathematically derived, that describes & defines the relationship between…**
    - **The moving tube; and,**
    - **The moving table; and,**
    - **The beam width as it exits the patient and interacts with the detector(s)**

**As important as mA or kVp!**

3

## What is "PITCH?"

- "PITCH"
  - **There are two equations that are relative**
    - **One equation for SDCT**
    - **A slightly different equation for MDCT**
      - **Must consider Cone beam geometry**

**As important as mA or kVp!**

4

## SDCT "PITCH" Equation
(Slice Collimation = Slice Thickness = Beam Width)

$$\frac{\text{Table Movement per Tube Rotation}}{\text{Slice Collimation}}$$

OR,

$$\frac{\text{Table Travel}}{\text{Beam Width}}$$

5

Calculate "PITCH" when at one tube rotation per second, table movement is 5 cm. Slice thickness is programmed at 2.5 cm.

- Solution:

$$\frac{\text{Table travel} = 5 \text{ cm}}{\text{Beam width} = 2.5 \text{ cm}} = 2$$

6

## MDCT (Beam)"PITCH" Equation

$$\frac{\text{Table feed in mm per 360 degree Rotation}}{\text{Beam Width}}$$

Where, Beam Width = # of Detectors x Slice Thickness

7

Calculate the PITCH for an MDCT protocol when table feed is 10 cm/sec, the scanner is 32 slice and slice thickness is 2.50 mm.

- Solution:

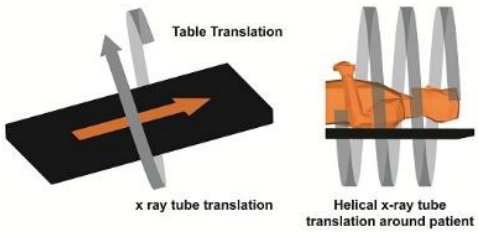
$$\frac{\text{Table Feed} = 100 \text{ mm/sec}}{\text{Beam Width} = 32 \times 2.50 \text{ mm}} = 1.25$$

(Detectors x Slice thickness)

8

## Why does “PITCH” occur?

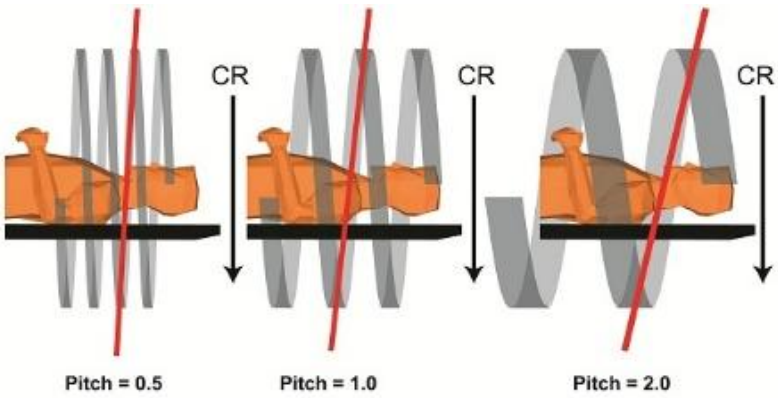
- “PITCH” happens because the motion of the patient through the gantry causes the beam to traverse the patient anatomy in a helical configuration similar to a corkscrew or helix




**The plane within which the tube travels is perpendicular to the horizontally indexing table and patient**

9

## “PITCH” Exists because Slice “PITCH” is Real!




As SLICE “PITCH” increases, the value of “PITCH” increases

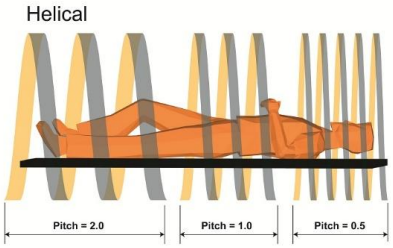
“PITCH” is the term that describes the relationship between tube rotation, table indexing and beam width at the detectors

10

# Some-"things" to consider regarding "PITCH?"

As important as mA or kVp!

- Changes in "PITCH" impact exam quality and patient dose
  - As "PITCH" increases, anatomy covered increases, dose decreases and resolution decreases
  - As "PITCH" decreases, anatomy covered decreases, dose increases and resolution increases




11

# "Pitch"- "the reality"…

The real definition:

- How fast the patient passes through the gantry; compared to,
  - mm or cm per second
- How fast the tube rotates around the patient; compared to,
  - Tube rotations per second
- How the exit beam impacts the detector system.
  - SDCT = slice thickness
  - MDCT = beam width
    - Multidetector systems increase scan speed


"PITCH" is the term that describes the relationship between tube rotation, table indexing and beam width at the detectors

12

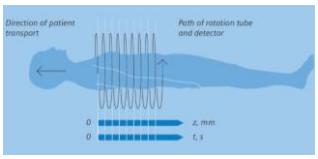
# What is "PITCH?"

- "PITCH"
  - A technical factor that is without a unit
  - Changes in "pitch" impact image quality
    - As "pitch" increases, resolution decreases
    - As "pitch" decreases, resolution increases
  - Changes in "pitch" impact patient dose
    - As "pitch" increases, dose decreases
    - As "pitch" decreases, dose increases


As important as mA or kVp!

13

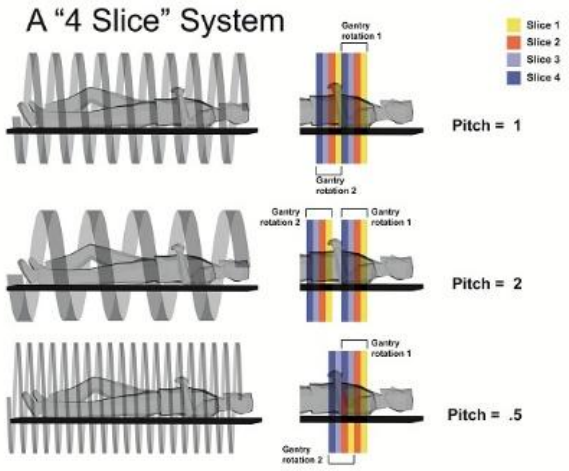
# Explaining "PITCH", another view…




- Important CONSIDERATIONS…
  - Index rate
    - **Patient travel through the gantry in either mm/sec or cm/sec**
    - **How fast the patient travels through the gantry**
  - Tube travel velocity
    - **How fast the tube rotates around the patient within the gantry**
    - **Rotations per second**
  - Slice thickness or Beam width?
    - **SDCT- Slice thickness along the Z axis**
    - **MDCT- Beam width along the Z axis**

14

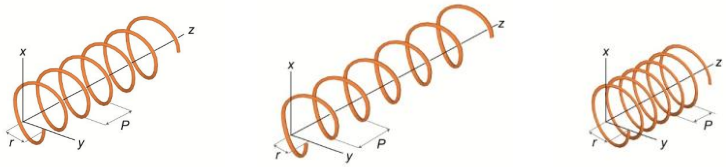
## HELIX Expansion, HELIX Contraction




15

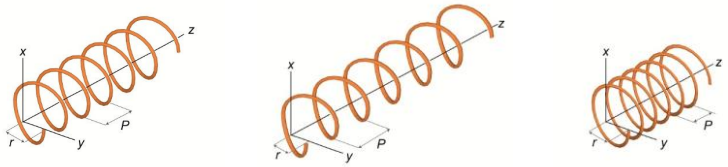
# Relative to Table Index Speed… "PITCH": helix expansion or contraction?

- There are 2 moving parts & beam width to consider…
  - The rotation of the tube within the gantry around the patient; The speed with which the patient advances through the gantry, and, the slice thickness or beam width at the detectors.
  - Ask yourself- Does the helix expand or contract?
    - As table index speed increases, the HELIX expands, "pitch" INcreases
    - As table index speed decreases, the HELIX contracts, "pitch" DEcreases



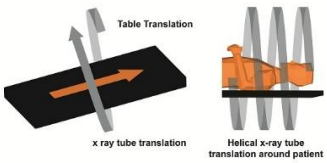
# Relative to Tube Rotation Speed… "PITCH": helix expansion or contraction?

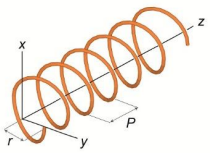
- There are 2 moving parts & beam width to consider…
  - The rotation of the tube within the gantry around the patient; The speed with which the patient advances through the gantry, and, the slice thickness or beam width at the detectors.
  - Ask yourself- Does the helix expand or contract?
    - As tube rotation speed increases, the HELIX contracts, "pitch" DEcreases
    - As tube rotation speed decreases, the HELIX expands, "pitch" INcreases




# Relative to Beam Width… PITCH: helix expansion or contraction?

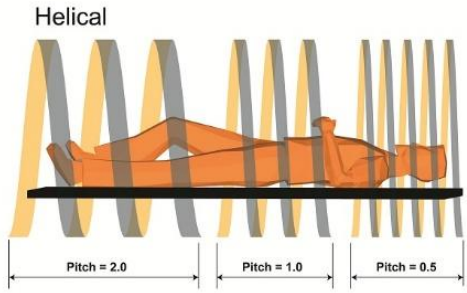
- There are 2 moving parts & beam width to consider…
  - The rotation of the tube within the gantry around the patient; The speed with which the patient advances through the gantry, and, the slice thickness or beam width at the detectors.
  - Ask yourself- Does the helix expand or contract?
    - As slice thickness or beam width increases, Pitch DEcreases
    - As slice thickness or beam width decreases, Pitch INcreases



# "PITCH" relationships…

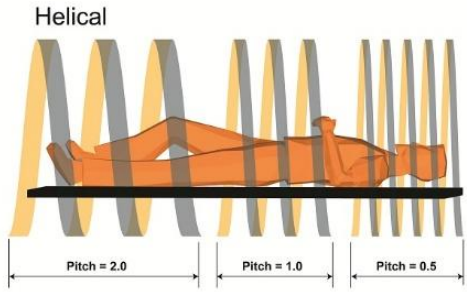
- INTERPRETING the diagram…
  - AS "P" increases:
  - "PITCH" increases,
  - dose decreases,
  - slice pitch increases,
  - anatomy covered per tube rotation increases; and,
  - resolution decreases




19

# "PITCH" relationships…

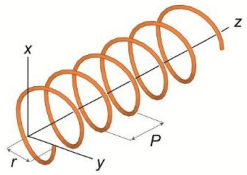
- INTERPRETING the diagrams…
  - AS "P" decreases:
  - "PITCH" decreases,
  - dose increases,
  - slice pitch decreases,
  - anatomy covered per tube rotation decreases; and,
  - resolution increases




20

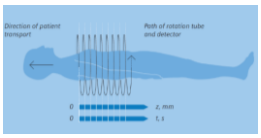
## "PITCH" as a technical factor

- In the most finite application, "PITCH" as a technical factor does possess inherent value;
- The numerical relationships are as follows:
  - Values of "PITCH" > 1
    - **As "P" increases, resolution decreases & dose decreases**
  - Values of "PITCH" < 1
    - **As "P" decreases, resolution increases & dose increases**




21

## "Pitch"- "In the Beginning"… P = 1, if…



- In an SDCT situation…
  - If table index speed is 1 cm (10mm) per second; and,
  - Tube rotation speed is one rotation per second; and,
  - If slice thickness is 1 cm (10mm)….

$$\frac{\text{Table Movement per Tube Rotation}}{\text{Slice Collimation}}$$

**10 mm (Table movement per rotation)**
**10 mm (Slice Collimation)**

OR,

$$\frac{\text{Table Travel}}{\text{Beam Width}}$$

22

# "Pitch"- "In the Beginning"…
# P = 1, if…

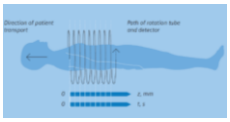
- So what happens to P if…
  - …If table index speed increases to 2 cm (20mm) per second? Will "Pitch" Increase or Decrease?

    $\frac{20 \text{ mm (Table movement per Tube rotation)}}{10 \text{ mm (Slice Collimation)}}$
  - …If slice thickness increases from 1 cm (10mm) to 2 cm (20mm)? Will "Pitch" Increase or Decrease? Returning to the Original…

    $\frac{10 \text{ mm (Table movement per Tube rotation)}}{20 \text{ mm}}$
  - BTW, Tube rotation speed increases; "Pitch" DEcreases

23

# "Pitch"- "In the Beginning"…
# P = 1, if…



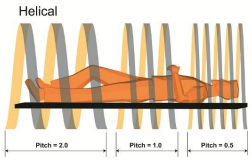
- In an SDCT situation…
  - If table index speed is 1 cm (10mm) per second; and,
  - Tube rotation speed is one rotation per second; and,
  - If slice thickness is 1 cm (10mm)….

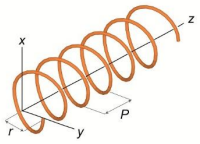
- So what happens to P if…
  - If table index speed DEcreases to 0.5 cm (5mm) per second; "Pitch" INcreases
  - Tube rotation speed DEcreases; "Pitch" INcreases
  - If slice thickness DEcreases from 1 cm (10mm) to 0.5 cm (5mm); "Pitch" DEcreases

24

## Some-"things" to consider regarding "PITCH?"

- "PITCH" occurs because tube travel within the gantry is in a plane that is always perpendicular to the indexing table, so…
  - the motion of the patient through the gantry causes
    - the beam to pass over the patient in a helical configuration similar to a corkscrew
  - Explains the need for "INTERPOLATION"




25

## Describing "PITCH" (another view)

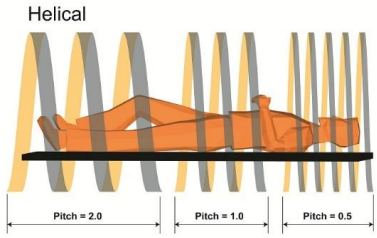
- Briefly, "PITCH" describes the basic relationship between…
  - Tube travel velocity-
    - the number of 360 degree rotations per second
  - Table indexing velocity-
    - the number in mm/sec or cm/sec that the table moves through the gantry
  - Z axis coverage
    - SDCT systems use slice thickness
    - MDCT systems use beam width

"PITCH" is the term that describes the relationship between tube rotation, table indexing and beam width at the detectors

26

# "PITCH", the term or the factor…

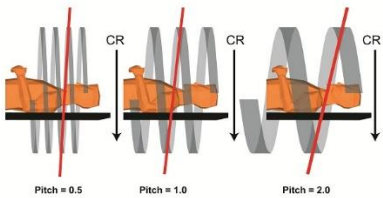
- Describes the MATHEMATICAL relationship between
  - Tube rotation velocity within the gantry
  - Table indexing velocity through the gantry
  - Beam width at the detector interface




27

# Why does "PITCH" occur?

- "PITCH" happens because the motion of the patient through the gantry causes the beam to traverse the patient anatomy in a helical configuration similar to a corkscrew or helix

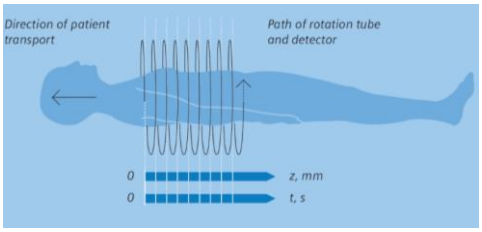



The plane within which the tube travels is perpendicular to the horizontally indexing table and patient

28

## "Pitch" impacts…

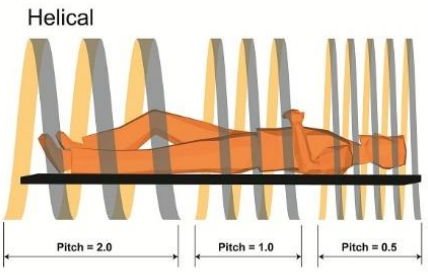
- Dose
- Resolution
- Anatomy covered
- Slice pitch




29

## Impacted by "Pitch"

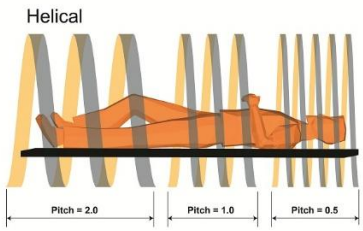
- Dose
  - As "pitch" increases, patient dose decreases
  - As "pitch" decreases, patient dose increases




30

## Impacted by “Pitch”

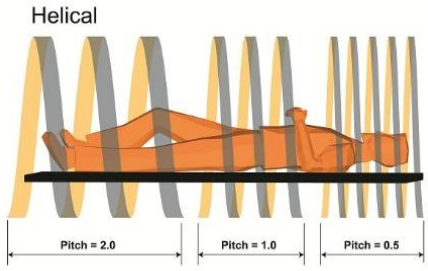
- Resolution
  - As “pitch” increases, resolution decreases
  - As “pitch” decreases, resolution increases




31

## Impacted by “Pitch”

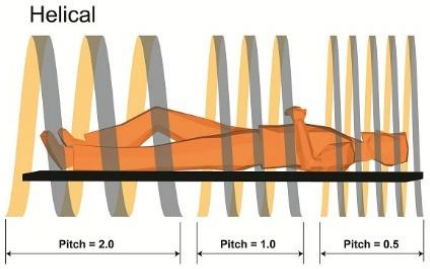
- Anatomy covered
  - As “pitch” increases, anatomy covered increases
  - As “pitch” decreases, anatomy covered decreases




32

## Impacted by “Pitch”

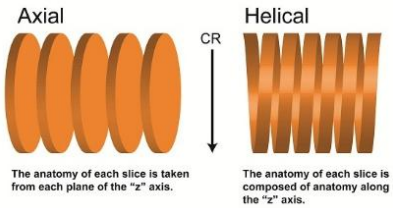
- Slice pitch
  - As “pitch” increases, slice pitch increases
  - As “pitch” decreases, slice pitch decreases



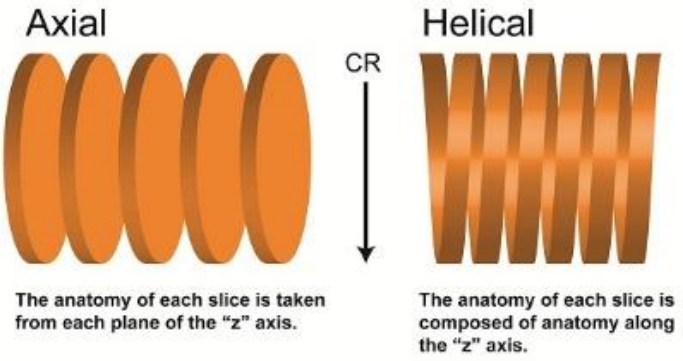

33

## The existence of Helical CT “PITCH” explains why Head exams are done in AXIAL mode

- WHEN Slice “PITCH” is vertical to the longitudinal “Z” axis, RESOLUTION WILL BE MAXIMIZED
- INTERPOLATION NOT REQUIRED
  - Conventional CT systems that are typically SDCT
  - Helical CT systems operating in the AXIAL mode



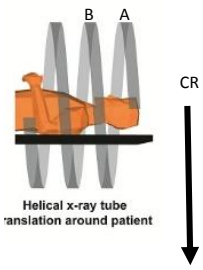

34




35

## Because of the "corkscrew"…

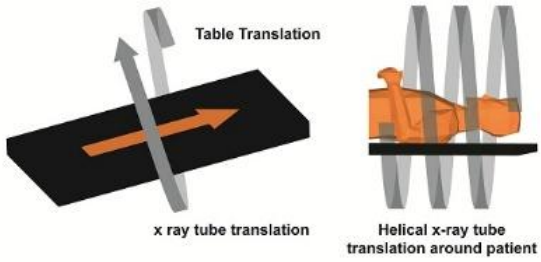
- In HELICAL scanning:
  - Where the x-ray beam enters the patient when exposure begins (A) is NOT where the x-ray beam ends up (B) when the tube has traveled one complete rotation




With patient travel head first…can you see how the beam entry would be the glabella? (A)
After one complete rotation beam entry at (B) is consistent with C-4.
Each "slice" is at a very slight angle to the perpendicular CR…this is "SLICE PITCH" or "PITCH"

36

# Explains the reason for INTERPOLATION!...

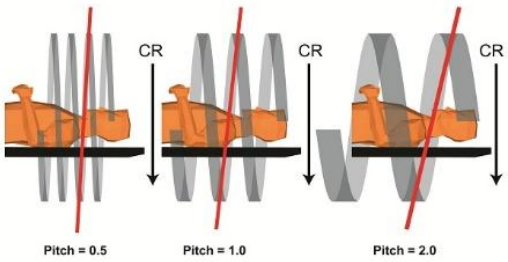



**"Guestimating" attenuation data when other values are known**

37

# What is "INTERPOLATION?" Why is it necessary?

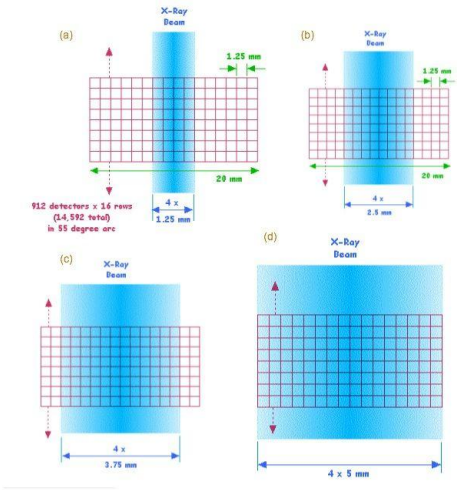
- "INTERPOLATION" is a necessary filtering function that occurs because of helical scanning geometry. The corkscrew movement causes the beginning and end "Z" axis points to be different for any given "slice."




**The plane within which the tube travels is perpendicular to the horizontally indexing table and patient**

38

**MDCT**: capturing more of the divergent beam that exits the patient




- As slice thickness or beam width increases, Pitch DEcreases
- As slice thickness or beam width decreases, Pitch INcreases

39

## Sample Systems…

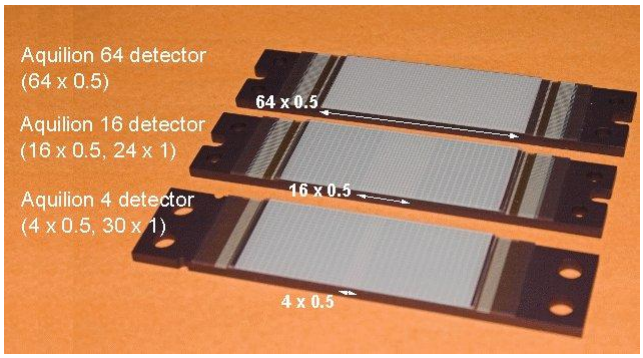



Table feed in mm per 360 degree Rotation

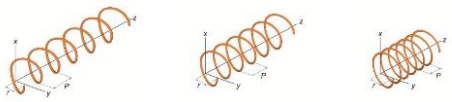
Beam Width

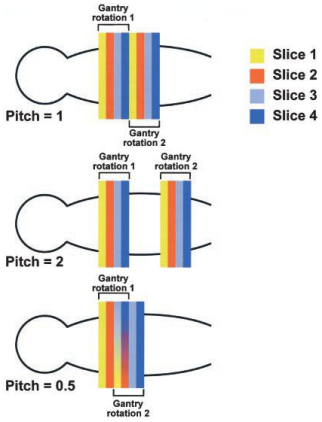
Where, Beam Width = # of Detectors x Slice Thickness

40

## "Pitch", the Helix, Dose & Resolution

- As the helix expands, "pitch" Increases
  - **Dose & Resolution DEcrease**
- As the helix contracts, "pitch" Decreases
  - **Dose & Resolution INcrease**





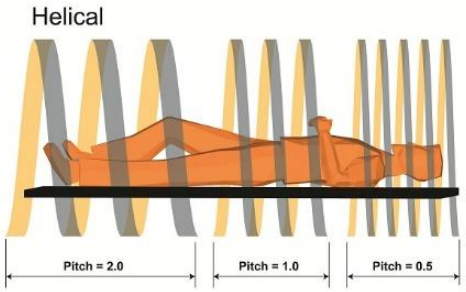

41

If all other factors remain constant…

What happens to "pitch" if…

…the table index velocity is increased?

Does the HELIX expand or contract?




**"Pitch" will increase**

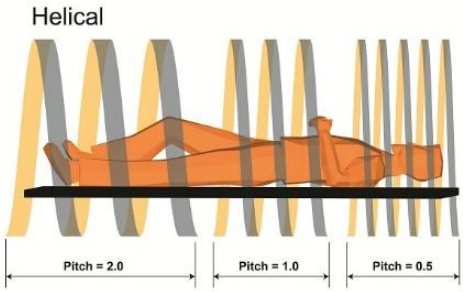
42

If all other factors remain constant…

What happens to “pitch” if…

…the tube rotation velocity increases…

Does the HELIX expand or contract?




**“Pitch” will decrease**

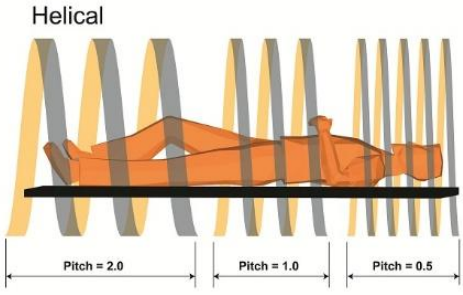
43

If all other factors remain constant…

What happens to “pitch” if…

…the number of detectors increases?

Does the HELIX expand or contract?




**“Pitch” will DEcrease**

- As slice thickness or beam width increases, Pitch DEcreases
- As slice thickness or beam width decreases, Pitch INcreases

44

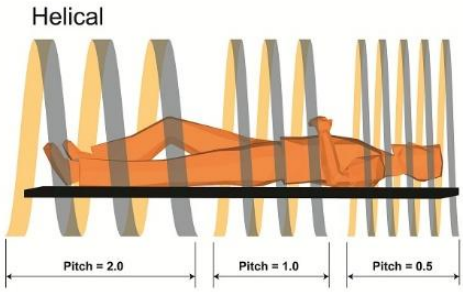
How would you DEcrease "Pitch" from 1.0 to 0.5?

How would you change tube velocity? **(Increase tube velocity)**

How would you change index velocity? **(Decrease index velocity)**

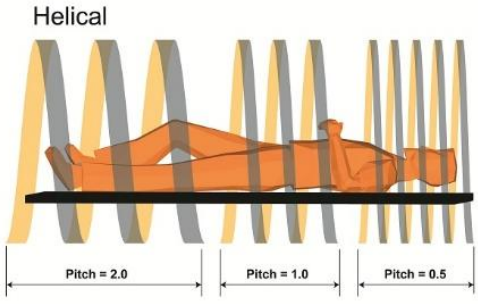
How would you change beam width? **(Increase beam width)**

In this Example…




45

In this Example…




How would you change "Pitch" to a value of 2.5 from 1.0?

1. Increase table index velocity? **Yes.**
2. Increase tube rotation velocity? **No.**
3. Increase beam width? **No.**

46

## Single Slice CT

**PITCH = 1 = Contiguous slices**

**PITCH > 1 = Gaps between slices**

**PITCH < 1 = Overlapped slices**

Principles of CT: Multislice CT*
Lee W. Goldman
Department of Radiation Therapy and Medical Physics, Hartford Hospital, Hartford, Connecticut

**"Because slice thickness and x-ray beam width are equivalent in SSCT, the value for pitch conveyed important information about the x-ray beam; a pitch of 1.0 meant that the x-ray beams from adjacent rotations were essentially contiguous. Pitches of greater than 1 implied gaps between the x-ray beams from adjacent rotations. Pitches of less than 1 implied x-ray beam overlap (and thus double irradiation of some tissue) and so were not clinically used."**

47

## Single Slice CT: "Detector Pitch"

Single Slice Scanner Equation

$$\frac{\text{Table Movement per Tube Rotation}}{\text{Slice Collimation}}$$

OR,

$$\frac{\text{Table Travel}}{\text{Beam Width}}$$

Typical Values are 0.7 – 1.5

48

**Single slice CT (SSCT)**

The term **detector pitch** is used and is defined as table distance traveled in one 360° gantry rotation divided by beam collimation [2].

For example, if the table travelled 5mm in one rotation and the beam collimation was 5mm then pitch equals 5mm / 5mm = 1.0.

Choice of pitch affects both image quality and patient dose[2]:

- P = 1.0 - x-ray beams are contiguous for adjacent rotations
- P > 1.0 - x-ray beams are not contiguous for adjacent rotations, i.e. there are gaps in between the x-ray beams and tissue is not irradiated
- P < 1.0 - there is x-ray beam overlap; i.e. a volume of tissue is irradiated more than once per scan

Thus a pitch > 1.0 results in decreased patient dose but also decreased image quality (through less projections obtained resulting in lower SNR). A pitch of < 1.0 results in better image quality but at higher patient dose.

Principles of CT: Multislice CT*
Lee W. Goldman
Department of Radiation Therapy and Medical Physics, Hartford Hospital, Hartford, Connecticut

## Multi Slice CT: 2 Terms

* General Electric: "Slice" Pitch

$$\frac{\text{Table feed in mm per 360 degree Rotation}}{\text{Slice Width}}$$

* Siemens, Toshiba, Marconi: "Beam" Pitch

$$\frac{\text{Table feed in mm per 360 degree Rotation}}{\text{Beam Width}}$$

Where, Beam Width = # of Detectors x Slice Thickness

50

## Multi Slice CT: "Beam" Pitch

**With the new definition, beam pitch for the example just given would be calculated as follows: pitch = table movement per rotation/(*n* × T) = 15 mm/(4 × 5 mm) = 0.75. Because beam pitch conveys similar information for MSCT as the original definition did for SSCT, it is the preferred definition in most situations (*2*).**

Principles of CT: Multislice CT*

Lee W. Goldman
Department of Radiation Therapy and Medical Physics, Hartford Hospital, Hartford, Connecticut

## "PITCH" PROBLEMS

1. Calculate the "PITCH" in a SSCT situation when table movement per tube rotation is 0.5 cm and slice thickness is 2.5 mm.

   "Detector" PITCH Equation:

   Table Movement per Tube Rotation

   Slice Collimation

   5 mm = 2

   2.5 mm

## "PITCH" PROBLEMS

2. Calculate the "PITCH" in a 16 channel MSCT situation when table movement per tube rotation is 10 cm and slice thickness is 5 mm.

"Beam" PITCH Equation:

$$\frac{\text{Table feed in mm per 360 degree Rotation}}{\text{Beam Width}}$$

**Where, Beam Width = # of Detectors x Slice Thickness**

$$\frac{\textbf{100 mm}}{\textbf{16 x 5 mm}} = \textbf{1.25}$$

***WHAT IF THE SYSTEM WAS A 64 SLICE SCANNER?***

$$\frac{\textbf{100 mm}}{\textbf{64 x 5mm}} = \textbf{0.3}$$

53

# *THANK YOU!*



54