CT brain perfusion survey in the State of California

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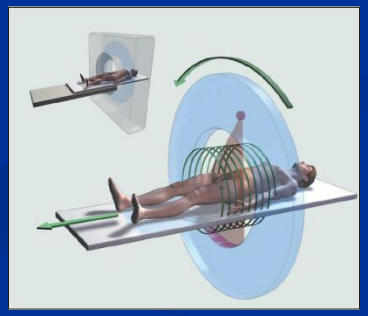
Topics to be covered

- Principles and parameters of CT
- Brain perfusion
- Brain perfusion investigation in California
- SB 1237 investigation

Principles of CT scanning

- CT is a method for acquiring and reconstructing an image of a thin cross section of body.
- Main components are an x-ray source and detectors . A fan-shaped x-ray beam scans the area of the body as the patient moves through.
- The series of body images are processed and reconstructed by a computer, producing 2D and 3D images.



Modes of CT scanning

- Multi-slice CT (MDCT): can acquire multiple slices in a single rotation.
- Spiral and Helical CT: scanner rotates along a spiral path continuously as the pt. couch moves through the gantry. No gaps between slices obtained in spiral scanning.

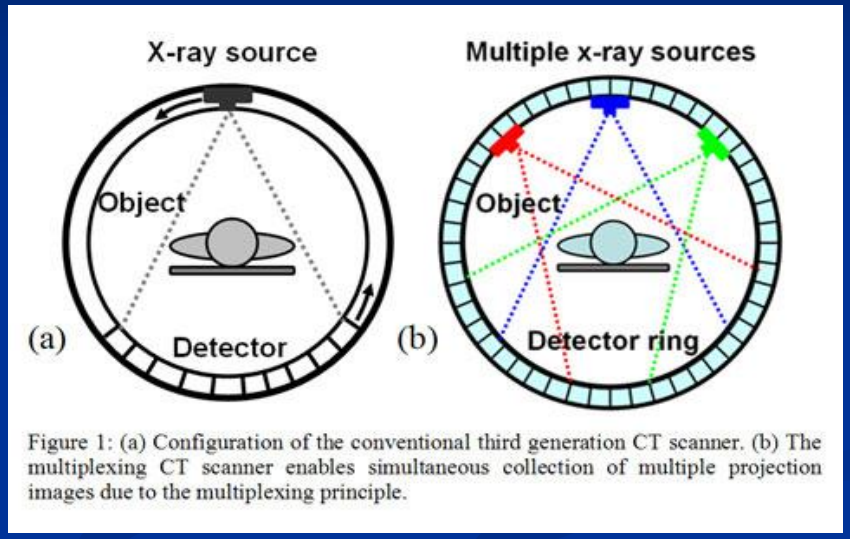
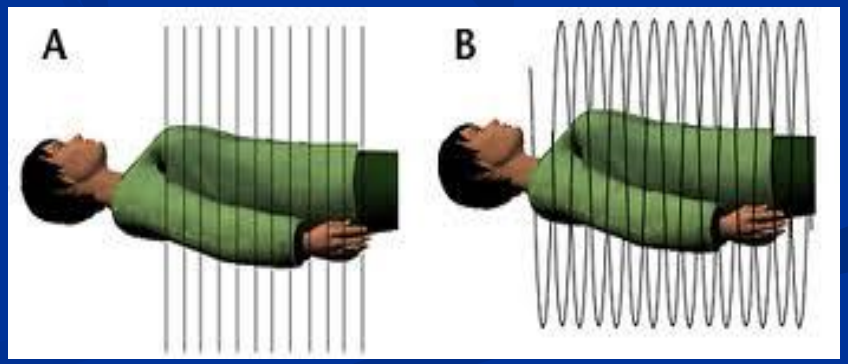


Figure 1: (a) Configuration of the conventional third generation CT scanner. (b) The multiplexing CT scanner enables simultaneous collection of multiple projection images due to the multiplexing principle.



Advantages of Multi-slice CT

- Large coverage and faster scan speed.
- Better contrast utilization.
- Less patient motion artifacts.
- Isotropic spatial resolution.

CT acquisition Parameters

- Tube potential (80-140 KVp)
- Tube current (20-500 mA)
- Scan time (0.5-4 seconds)
- Beam filtration “bow-tie filter”
- Pitch (0.5-2) – helical (spiral)
- Collimation/ Slice width (0.5-10 mm)

CT Dosimetric Parameters

1- CTDI $_{vol}$ (mGy) which indicates the average dose in the scanned region (Slice)

2- DLP (mGy.cm) which indicates the exposure from the entire CT examination *DLP* (mGy.cm) = *CTDI*vol (mGy) x *scan length* (cm)

3- Effective dose (mSv) which indicates the radiation risk of the entire CT scan.

CT Brain Perfusion

- Is diagnostic imaging technique that allows rapid qualitative and quantitative assessment of the brain and its vessels.

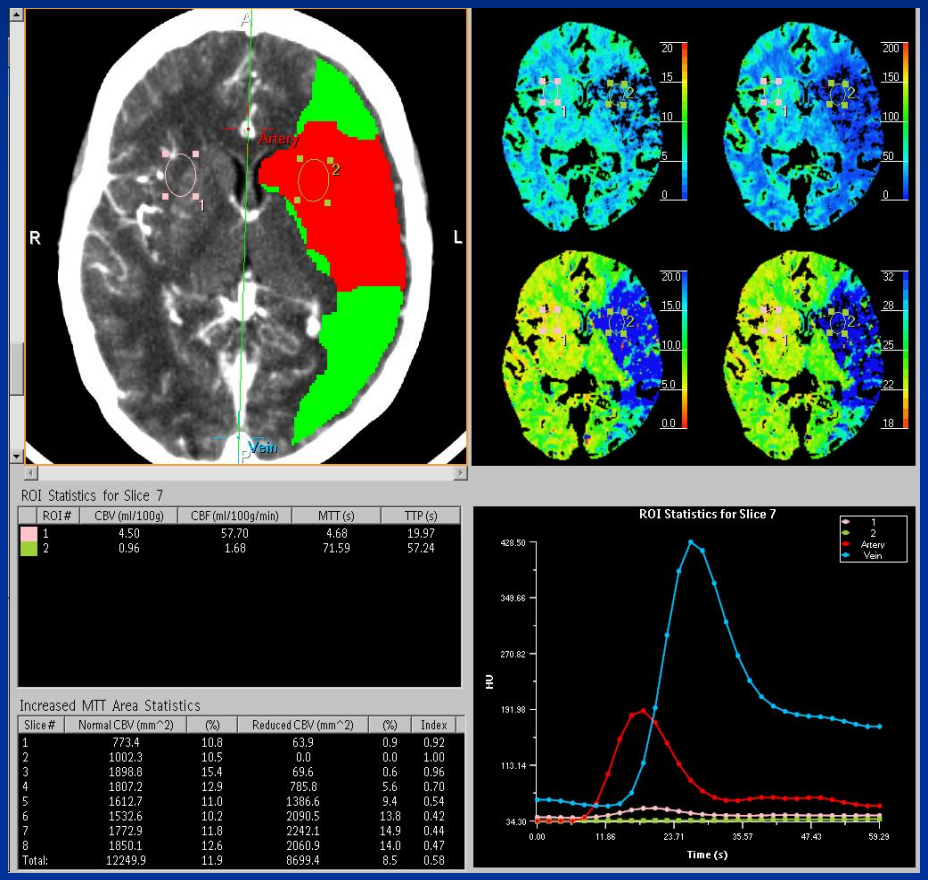
- CT perfusion imaging can be used on any organ, it is currently used mainly for brain perfusion studies e.g.
  - Acute ischemic stroke (85%)
  - Brain tumor vascularization

- If ischemic stroke is diagnosed, a thrombolytic drug, recombinant tissue plasminogen activator (rtPA) may be administered via I.V. within 3 hours of onset of symptoms

Brain Perfusion Parameters

- **CBV** (Cerebral Blood Volume): volume of blood per unit volume of tissue (normal range 4-5 ml/100g).
- **CBF** (Cerebral Blood Flow): volume of blood flow per unit volume of tissue per minute (normal range in grey matter, 50-60 ml/100g/min).
- **MTT** (Mean Transit Time): the time difference between the arterial inflow and the venous outflow (Second).
- **TTP** (Time to Peak): the time from the beginning of the contrast material injection to the maximum concentration of contrast material within a region of interest.

Brain Perfusion and summary maps



- Left Cerebral Infarction

- Infarct area in red and penumbra area in green

Typical Brain Perfusion Protocol

1- **None-enhanced head CT**

a - 2.5 mm axial cuts from skull base to vertex

b – 100kVp, 200 mAs

2- **Dynamic CT perfusion**

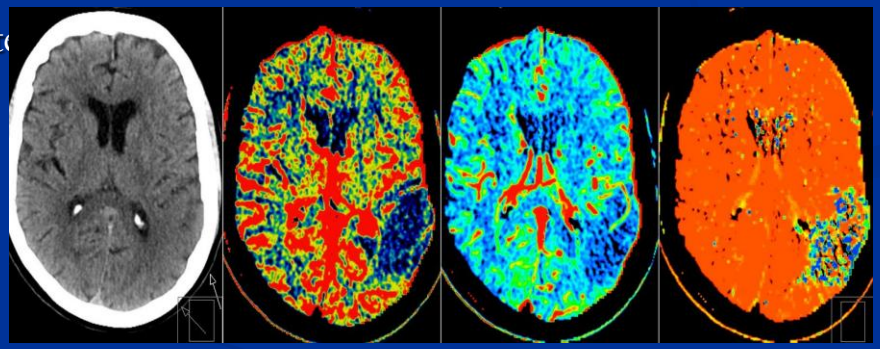
a- 40 mL iodinated contrast

b- 18- or 20-gauge IV access; 5 mL/sec injection rat

c- 6-second scan delay, 45-second scan time

d- 80 kVp, 100 mAs

e- "Cine scan mode", 5-mm slices



3- **CT angiogram**

a- 40 mL iodinated contrast

b- 5cc/sec injection rate

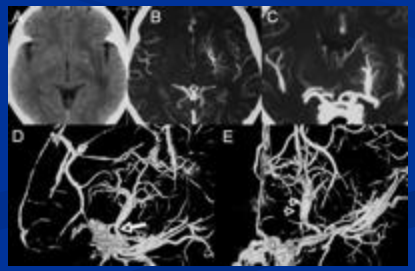
c- 18- or 20-gauge IV access; 4 mL/sec injection rate

d- 25-second scan delay

e- 100 kVp, 250 mAs

f- Spiral CT acquisition, 0.625-mm slices, pitch of 1:1

g- Coverage from left atrium to vertex



Brain perfusion investigation in California

- Cedar Sinai hospital – within 18 months, 269 patients had received high doses of radiation for their CT brain perfusion imaging.
- Cedar Sinai patients received maximum CTDI vol **4286**mGy/brain perfusion
- Recommended average $CTDI_{vol}$ <**500**mGy (FDA & CRCPD)

Brain Perfusion Overdose

- Hair loss in patients who received radiation overdoses

State wide CT inspection for Brain Perfusion Studies

- RHB conducted a state wide inspection of 47 facilities and 61 CT scanners within a period of 8 months.
- Survey (questionnaire)
- Physical measurement of radiation dose and recording of all parameters in brain perfusion studies on any CT unit.

CT Survey

- Facilities certification (Stroke Centers)
- Accreditation of CT units (ACR)
- History of brain perfusion (as early as 2002)
- Brain perfusion protocol(manufacturer or in-house modification)
- Technologists certification (ARRT) knowledge of CTDI vol and DLP
- Display of CTDI vol and DLP on Radiologist's work station
- Number of protocols
- Recording of radiation dose parameters i.e. CTDI vol and DLP (PACS)
- Responsibility within the Department (Radiologist, lead CT tech)
- First line of contact in case of over exposure event (engineer, radiologist, supervisor, medical physicist)
- Security of the protocol on a CT scanner (password protected)
- Existing of a procedure for changing a protocol on a CT unit

CT physical Inspection

- RTI Barracuda survey meter with 100mm CT probe.
- 16 cm Lucite head phantom.
- Axial scans with stationary table.
- All the exposure factors and technical parameters of brain perfusion protocol were recorded such as kVp, mA, total collimation and total scan time.

CT make and models

Manufacturer	Model	Slices
GENERAL ELECTRIC	(21) LS VCT *	64
(40)	(14) LS *	4, 8, 16
	(2) Discovery	64
	(1) LS Discovery	64
	(1) Bright Speed	16
	(1) LS Pro	8
SIEMENS	(1) Biograph Pet	64
(15)	(9) Somatom Sensation	16, 64
	(4) Somatom Definition	64
	(1) Dual Energy	64
TOSHIBA	(5) Aquilion *	16, 64
(7)	(2) Aquilion One	320

*** models with recorded elevated radiation exposures**

( ) represent number of CT scanners

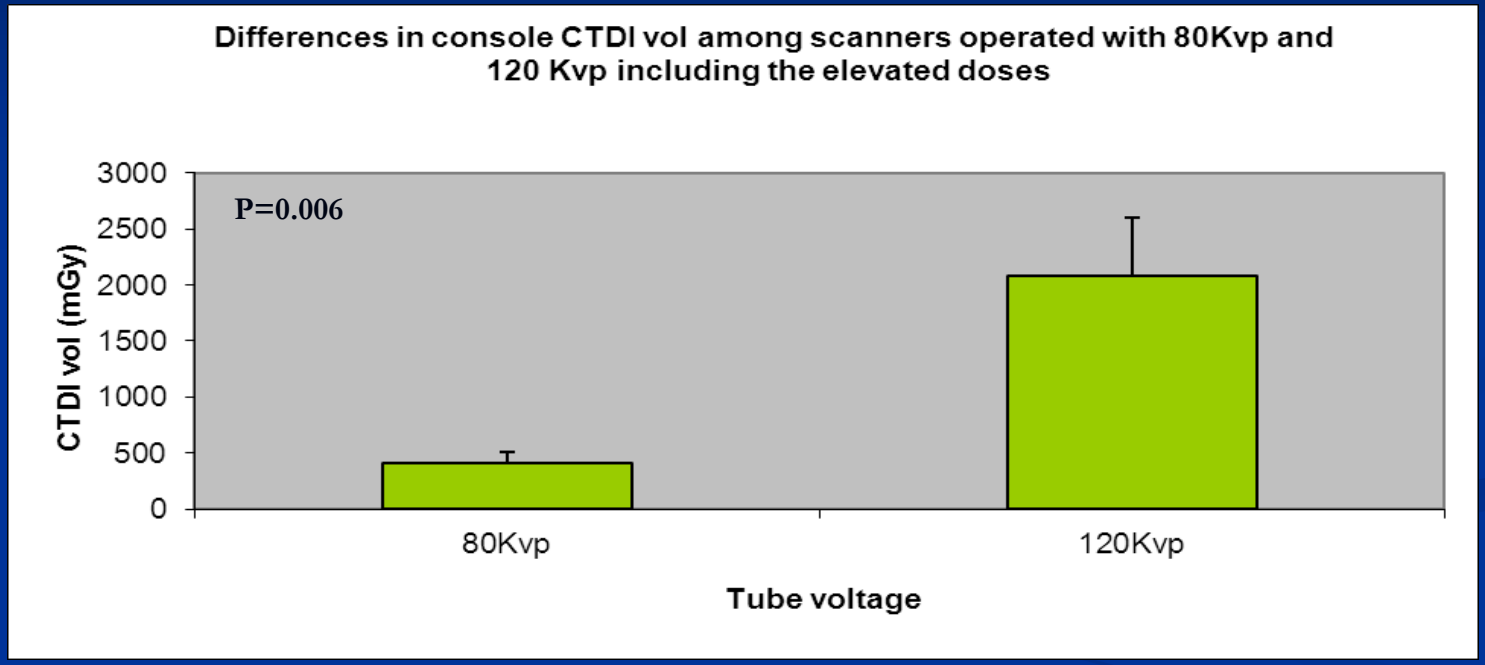
Inspection Results

Facility	CTDI vol (mGy)
- Cedar Sinai	**4286, 2648**
- Glendale Adv. Med. Ctr.	**2341**
- LAC-USC	**3650**
- Bakersfield Memorial	**2684**
- Cal Pacific Davies	**2341**

Make and Model of CT scanners with elevated radiation doses in their Brain perfusion protocol

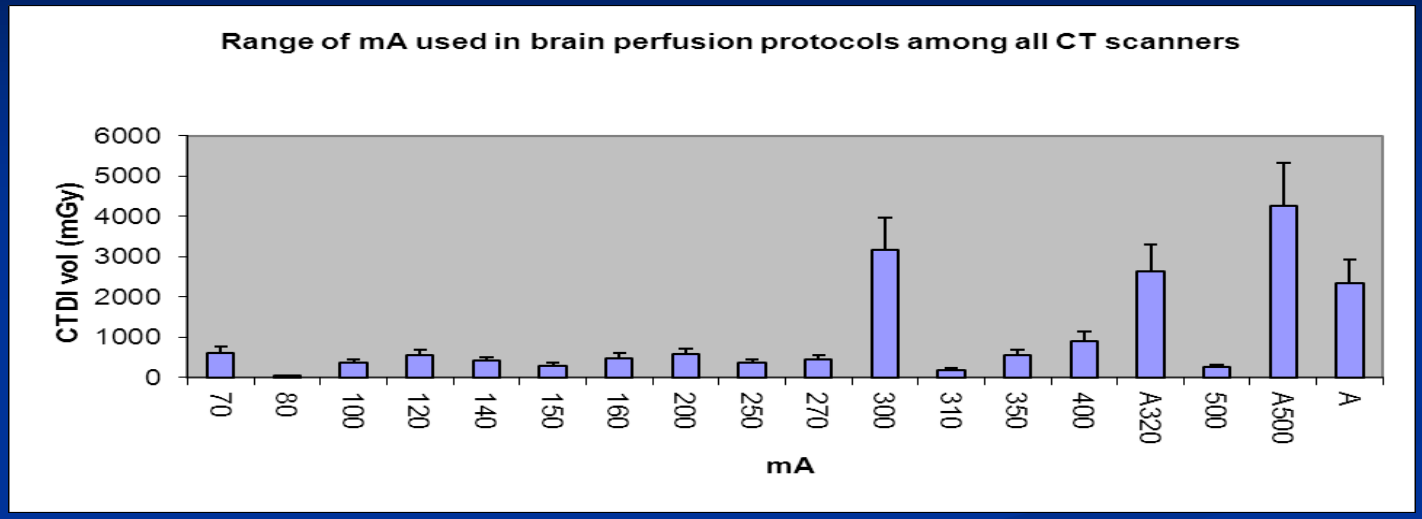
Manufacturer	Model	Slice	kVp	Collimation (mm)	mA	Scan Time (Sec)	CTDI vol (mGy)	Similar Models Avg±SD CTDI vol (mGy)
GE	LS VCT	64	120	40	500A	40	4286	447±141
	LS VCT	64	100	40	400	50	2361	
	LS	16	120	20	320A	40	2648	424±133
	LS	16	120	20	A	45	2341	
TOSHIBA	Aquilion	64	120	32	300	60	3650	745±267
	Aquilion	16	120	32	300	45	2684	

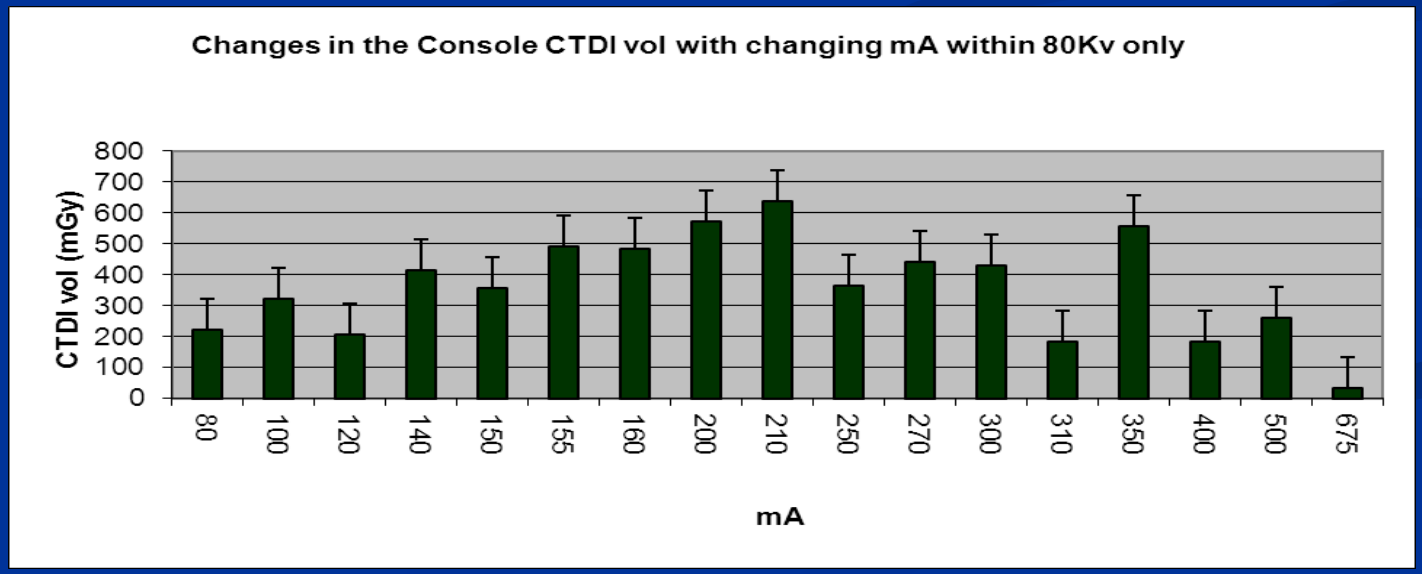
KVp vs. CTDI $_{vol}$



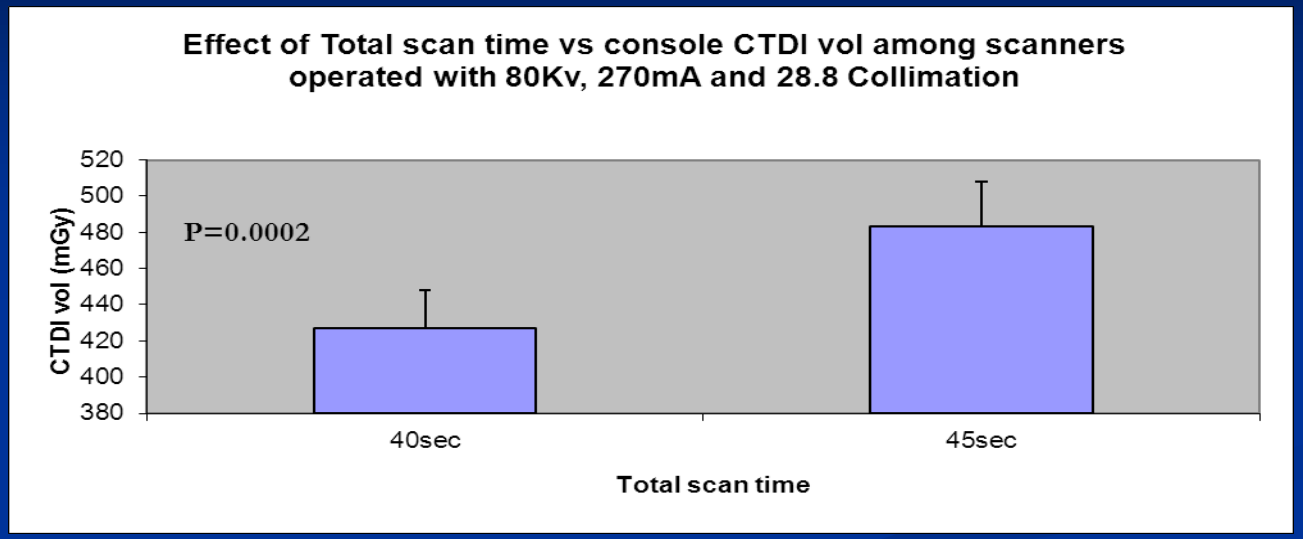
Two tailed student t-test with P values 0.001 were used for significance in all statistical analysis.

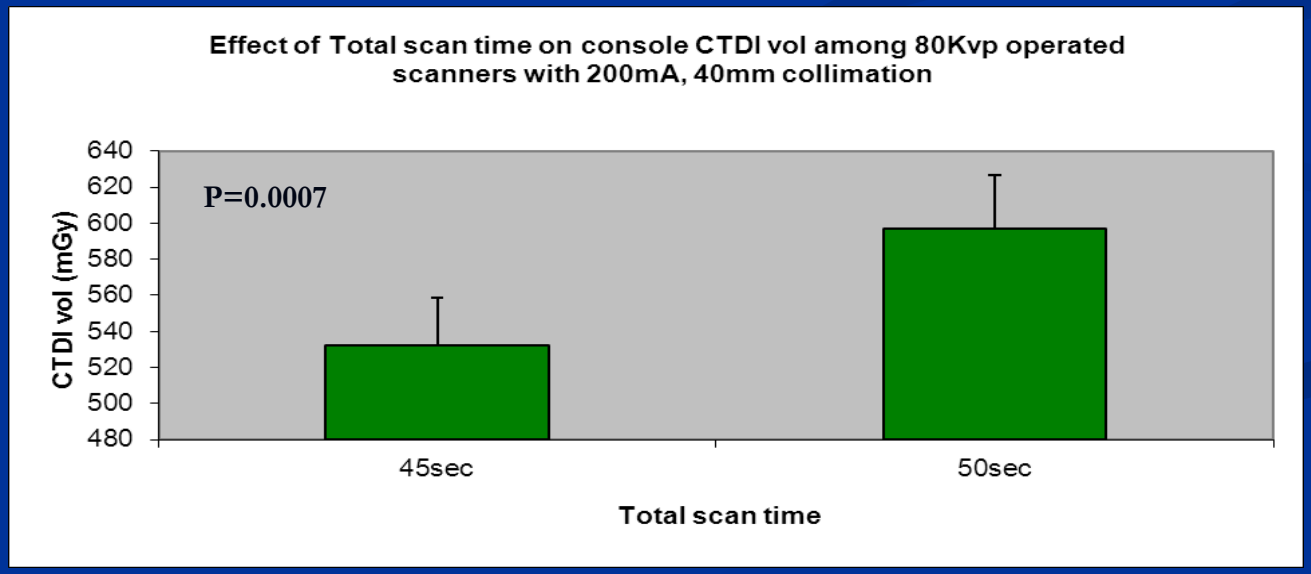
mA vs. CTDI $_{vol}$



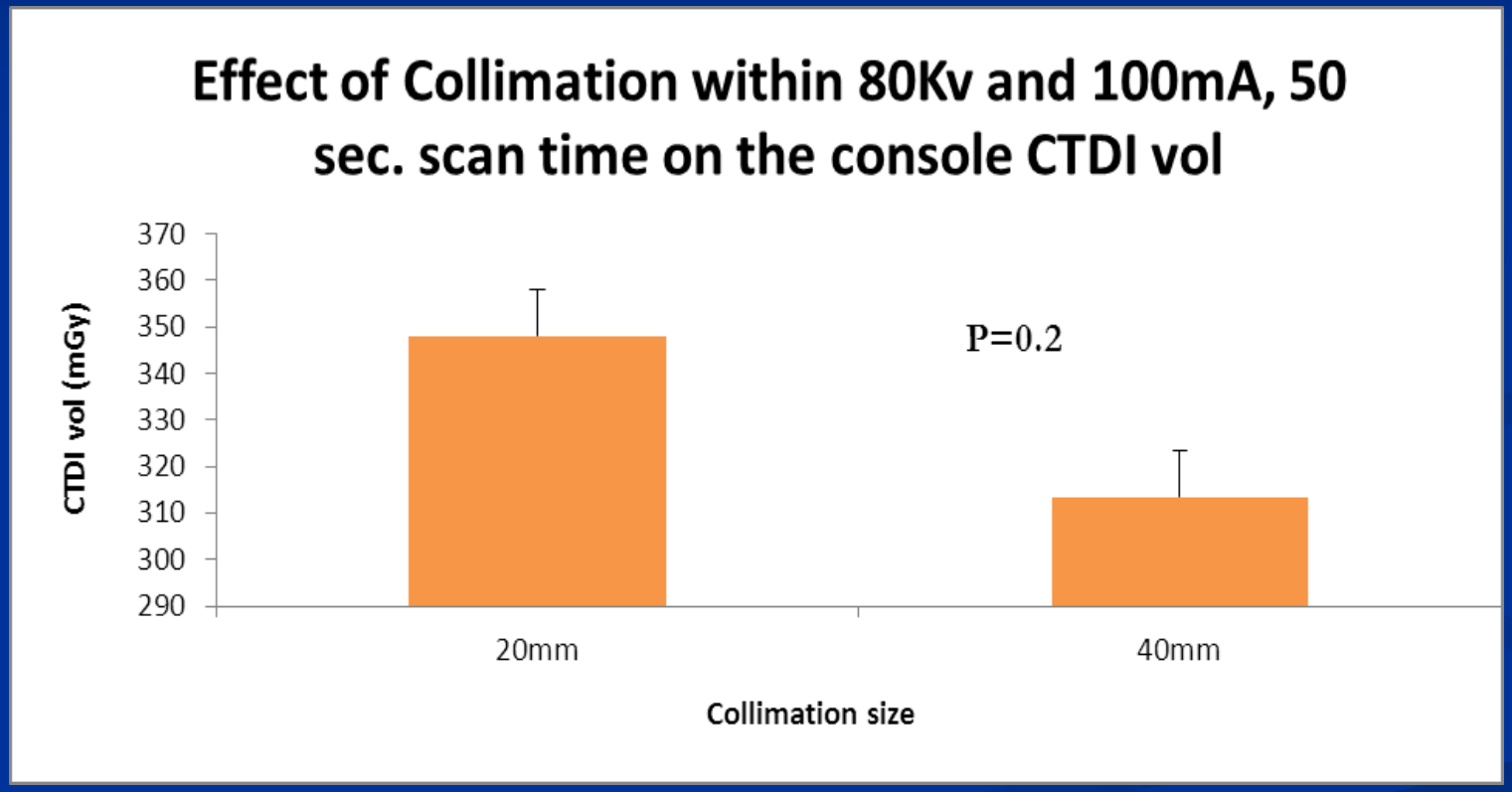


Total Scan time and CTDI $_{vol}$

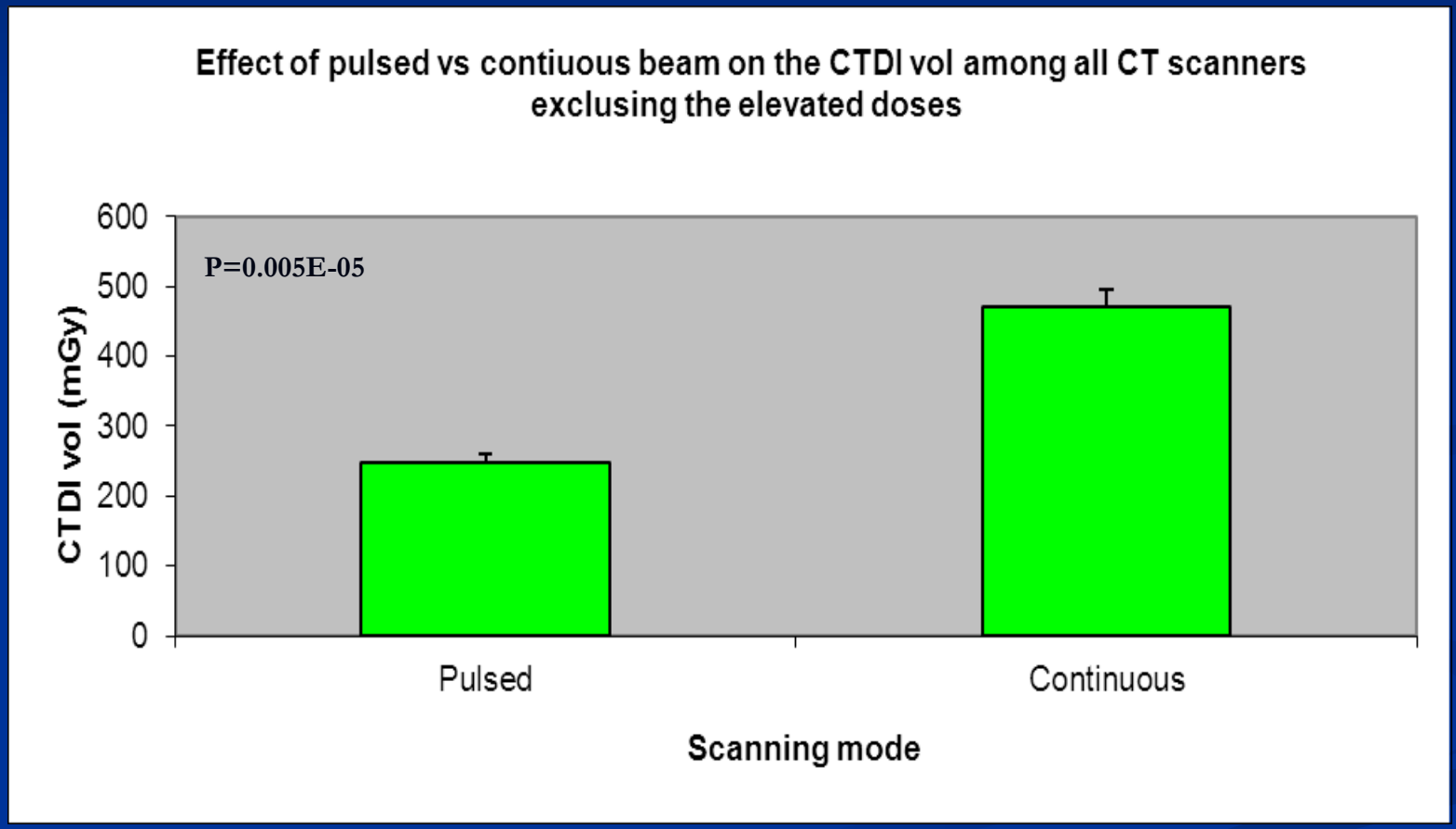




Total Collimation vs. $CTDI_{vol}$



Pulsed beam and CTDIvol



Biologic effects of low dose radiation in CT brain perfusion

- Effects not known!
- Organs at risk:
  - Lens of the eye (Cataract:>1-2 Gy)
  - Hair loss & Skin Erythema (1-3 Gy)
  - Thyroid gland (Cancer: >5Gy)
  - Brain parenchyma (Cancer: 5% per Sv; NCRP)

Conclusion on CT Survey and Inspection

- The elevated radiation doses not due to machine failure but due to human error and misadministration.
- Insufficient education and awareness of individuals involved in CT Brain perfusion studies.
- In order to maintain ALARA a Reference Radiation Level for CT Brain perfusion study should be defined.
- Changing the acquisition parameters (kVp, mA, Collimation, Total scan time etc.) would reduce patient dose in the CT brain perfusion study.

SB 1237

- This legislation was enacted in response to multiple events where patients were exposed to excessive radiation by diagnostic CT scanners
- Became effective January 1, 2011
- H&S Code Section 115113, recently enacted by SB 1237

Incident

- February 17, 2011 the hospital reported to RHB.
- A 69 yr. old patient was undergone Abdominal/pelvic CT scan twice.
- This incident was reported under CA Health and Safety Code Section 115113(a)(2): CT X-ray irradiation of a body part other than that intended by the ordering physician if one of the following dose values are exceeded:

(A) 0.05 Sv (5 rem) effective dose equivalent

(B) 0.5 Sv (50 rem) to organ or tissue

(C) 0.5 SV (50 rem) shallow dose equivalent to the skin

Chronological order of event

- February 8, 2011, the physician requested an abdominal/pelvic CT scan.
- February 10, 2011; the above order was carried out and the scan finding was a right lower lung lesion.
- February 10, 2011; the physician orders a "CT Chest scan' for a "nodule/mass workup".
- February 14, 2011; the patient received a repeat CT scan of the abdom/pelvis instead of "Chest CT scan".
- February 14, 2011; the radiologist discovers the wrong scan.
- February 14, 2011; the patient was contacted and rescheduled for CT of the chest.
- February 15, 2011; the CT scan of the chest was completed.

Abdominal/Pelvic CT scan

Equipment: GE Lightspeed-16 scanner

In house (abdominal/pelvic) protocol: 120KVp, Auto-mA, 0.8 sec scan time, pitch=0.938 with 16x1.25mm collimation(20mm total collimation)

Total scans Pt. received:

- Pre-contrast (abdominal/pelvic)
- Post-contrast (abdominal/pelvic)
- AP/Lateral pair view (scout)
- Post-contrast AP-KUB view (scout)

Effective Dose Calculation

Parameter	Pre-contrast Scan	Post-contrast Scan	Total
Scan Length	49.125 cm	49.125 cm	
$CTDI_{vol}$	21.4 mGy	27.22 mGy	
Dose-Length Product (DLP)	1115.56 mGy-cm	1418.84 mGy-cm	
ImPACT Calculated Effective Dose	22 mSv	27 mSv	**49 mSv**

Effective Dose Calculation

The Effective Dose from 3 scout views was estimated using three different methods:

- Stanford Dosimetry, LLC, " RADAR Medical Procedure Radiation Dose Calculator" **4.08 mSv**
- X-rayRisk.com **3.9 mSv**
- Common Radiation Exposures **3.33 mSv**
- average value of **4.0 mSv** was used for total contribution of the 3 scouts.

Total Effective Dose

- The resulting Total Effective Dose for this incident:

49mSv + 4 mSv = **53 mSv**

Effective dose exceeds 50 mSv, reportable.

SB1237

How should the facility notify CDPH of an event?

- The information provided to CDPH should include the following:
- Person making report, job title, contact information
- Date(s) of event
- Facility information
- Radiation generating equipment specifics (i.e. manufacturer, model number, and software version)
- Radiation generating equipment settings
- Operator's name
- Patient's physician name and contact information
- Copy of physician's order for CT or radiation therapy treatment plan
- Explanation as to reason for reporting event
- Copies of internal investigation reports (include cause and corrective action to prevent reoccurrence)
- Patient dose calculations (include methodology)
- Copies of letters sent to the patient and physician.

Q & A?