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Radiology

STANDARDIZATION OF CECT ABDOMEN PROTOCOL FOR APPENDICITIS, OVARIAN MASS AND HEPATOCELLULAR CARCINOMA

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KEYWORDS :

INTRODUCTION

Fundamentals Of CT Physics

Computed tomography was first designed by British engineer Godfrey N. Hounsfield of EMI laboratories and Allan Macleod Cormack of Tufts University in 1971.

Computed Tomography: Computed Tomography combines X-ray radiation and radiation detectors coupled with a computer to create a cross sectional image of any part of the body.

Principle: The basic principle behind Computed Tomography is that internal structures of an object can be reconstructed from multiple projections of the body.

History: The CT scanner is a triumph of ingenuity in engineering and applied physics. Its unparalleled evolution over the past 50 years is a testament to the power of academic and industry collaboration across many disciplines in medicine, science, and engineering. In New et al's 1974 description of the first Electric and Musical Industries (EMI) scanner in the United States, the acquisition of one transverse section required 5 minutes of scanning. Current CT scanners can acquire multiple transverse sections in <1 second, representing an enormous increase in efficiency.

By 1980, third generation rotate-rotate geometry became the dominant approach, and it has remained so to this day. Through the 1980s, CT scanners acquired images in an incremental step-and-shoot mode such that the examination table was stationary during acquisition of a transverse image from a 360° rotation of the gantry. The table would then move to the next scanning position before another scan was initiated, thereby imposing an interscan delay of 10 seconds in the early 1980s that decreased to 1–2 seconds by 1990. Although this mode of acquisition was the cornerstone of early CT applications, it had important shortcomings. For example, it resulted in longitudinal mis-registration due to discontinuities between transverse sections, it was prone to motion artifacts, it was impractical for the acquisition of contiguous sections thinner than 5–10 mm, and it precluded consistent imaging through highly dynamic phases of vascular and parenchymal enhancement. This all changed in 1990 with the introduction of continuous gantry rotation on a slip ring with associated continuous table translation tracing a spiral or helical path. The ability to scan the entirety of the chest or abdomen in a single breath hold by using thin contiguous cross sections that could be reconstructed at arbitrary increments was a revelation from which many key clinical developments emerged. Reductions in scan time continued through the 1990s with the introduction of increased scan pitch and sub second gantry rotation. The next important breakthrough came in 1998 with the four–detector row CT scanner. Multi detector CT enabled the development of retrospective electrocardiographically gated spiral scanning, which yielded contrast material–enhanced images of the heart and coronary arteries. Four–detector row CT gave way to 16–detector row CT in 2002 and then 64–detector row CT in 2004. In 2006, with the introduction of a dual-source dual detector CT scanner capable of 83 ms temporal resolution that furthered the robustness of coronary artery imaging . Finally in 2010, a 16-cm-wide 320-row detector system was introduced that enabled single heart-beat imaging with a stationary table.

Contrast Enhanced CT Scan

The purpose of contrast-enhanced CT (CECT) is to find pathology by enhancing the contrast between a lesion and the normal surrounding structures.

Sometimes a lesion will be hypovascular compared to the normal tissue and in some cases a lesion will be hypervascular to the surrounding tissue in a certain phase of enhancement. So it is important to know in which phase a CT should be performed depending on the pathology that you are looking for.

Indications

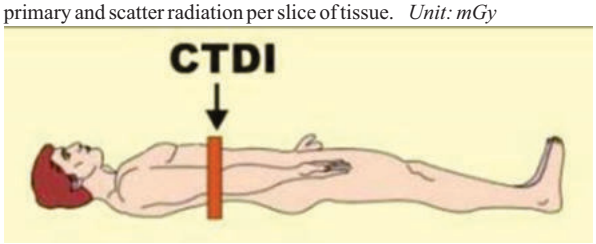
- o abdominal pain
- o abdominal sepsis
- o bowel obstruction
- o postoperative complications
- o trauma
- o vascular compromise, e.g. aortic aneurysm

Limitations

- • uses ionizing radiation for multiple phase studies
- • requires iodinated IV contrast
- o risk of renal impairment
- o risk of anaphylactic reaction

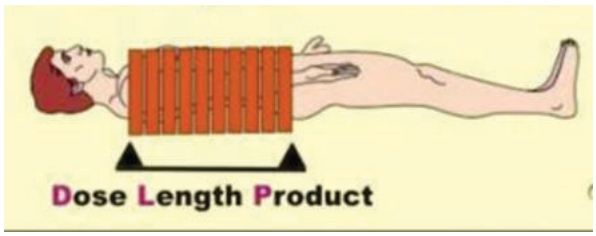
CT Dose Descriptors

CTDI: Provides a measurement of the radiation dose due to the primary and scatter radiation per slice of tissue. *Unit: mGy*



Dose Length Product: The DLP provides a measurement of the total amount of dose to the entire scan coverage. CTDI volume is not dependent on the scan length whereas DLP is directionally proportional to the scan length. Its unit is mGy.cm

DLP = CTDI volume X Scan Length



Effective Dose: It is the dose descriptor that reflects the biological sensitivity of irradiated region of interest.

E= DLP x k factor; UNIT: mSv

REGION OF BODY	k (mSv mGy-1 cm-1)
HEAD	0.0021
NECK	0.0059
HEAD AND NECK	0.0031
CHEST	0.0140
ABDOMEN &PELVIS	0.0150

Anatomy

Anatomy Of Liver

- The liver is the largest gland in the body, weighing between 1 and 2.3 kg
- Location- It is situated in the upper part of the abdominal cavity occupying the greater part of the right hypochondriac region, part

of the epigastria region and extending into the left hypochondriac region.
- Shape- it is Shaped like a cone and it appears in dark reddish in colour
- Its upper and anterior surfaces are smooth and curved to fit the under surface of the diaphragm its posterior surface is irregular in outline.
- Blood supply-The hepatic artery and the portal vein take blood to the liver. Hepatic veins are leave the posterior surface and immediately enter the inferior vena cava just below the diaphragm

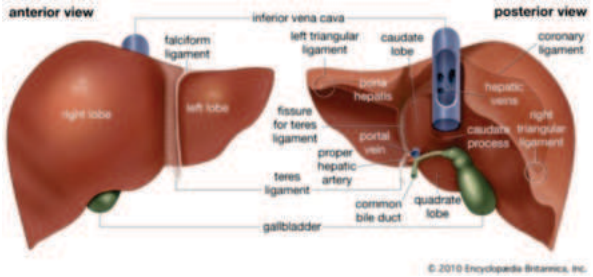


Fig.1 – This Figure Represents The Anatomical Image Of Liver

Hepatocellular Carcinoma:
Hepatocellular carcinoma (HCC) is the most common primary malignancy of the liver. It is strongly associated with cirrhosis, from both alcohol and viral etiologies. HCC constitutes approximately 5% of all cancers partly due to the high endemic rates of hepatitis B infection.

Clinical Presentation:
The presentation is variable and, in affluent nations, is often found in the setting of screening programs for patients with known risk factors . Otherwise, presentation may include:
- constitutional symptoms
- jaundice
- portal hypertension from the invasion of the portal vein
- hepatomegaly/mass
- hemorrhage from tumor.

Radiographic Feature In CT:
Several patterns can be seen, depending on the subtype of hepatocellular carcinoma. Enhancement pattern is the key to the correct assessment of HCCs.

Usually, the mass enhances vividly during late arterial (~35 seconds) and then washes out rapidly, becoming indistinct or hypoattenuating in the portal venous phase, compared to the rest of the liver.

Additionally, they may be associated with a wedge-shaped perfusion abnormality due to arterioportal shunts (APS), and this, in turn, can result in a focal fatty change in the normal liver or focal fatty sparing in the diffusely fatty liver. A halo of focal fatty sparing may also be seen around an HCC in an otherwise fatty liver.

Portal vein tumor thrombus can be distinguished from bland thrombus by demonstrating enhancement.

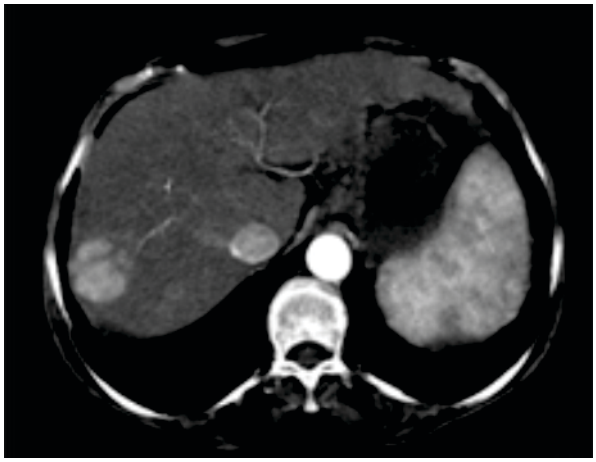


Fig .2: CT Showing HCC In Arterial Phase

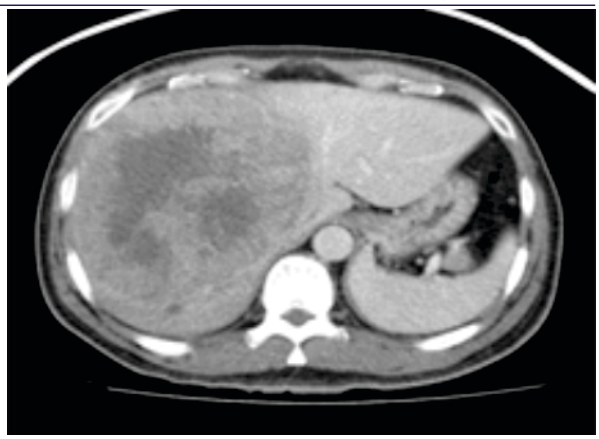


Fig.3: CT Showing HCC In Portal Phase

Appendix
Appendix is also known as vermiform appendix and it is a vestigial hollow tube that is closed at one end and is attached at the other end to the cecum, a pouch like beginning of the large intestine into which the intestine empties its contents.

The appendix is usually 8 to 10 cm long and less than 1.3 cm wide the cavity of the appendix is much narrower where it joins the cecum than it is at its closed end.

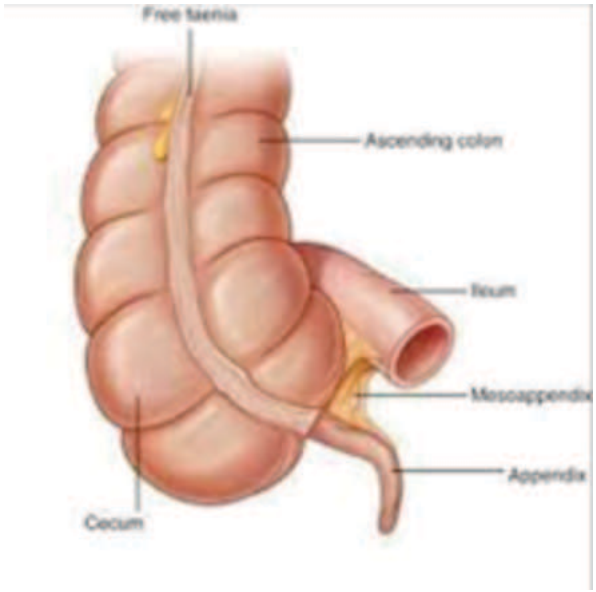


Fig.4: Anatomy Of Appendix

Appendicitis: is inflammation of the vermiform appendix. It is a very common condition in general radiology practice and is one of the main reasons for abdominal surgery in young patients. *CT is the most sensitive modality to detect appendicitis.*

Clinical Presentation
General signs and symptoms include
- fever
- localized pain and tenderness
- o right lower quadrant tenderness over appendix (i.e. McBurney sign)
- o pelvic pain, diarrhea, and tenesmus (pelvic appendix)
- o flank pain (retrocecal appendix)
- o groin pain - appendix within an inguinal hernia (Amyand hernia) or a femoral hernia (De Garengeot hernia)
- o right upper quadrant pain (subhepatic appendicitis)
- leukocytosis
- nausea and vomiting
- atypical location:
- o within the pelvis (30%)
- o extraperitoneal (5%)
- o left iliac fossa (rare), found in patients with a long appendix,

intestinal malrotation, situs inversus and those with a mobile cecum.

Radiographic Feature In CT

CT is highly sensitive (94-98%) and specific (up to 97%) for the diagnosis of acute appendicitis and allows for alternative causes of abdominal pain also to be diagnosed. The need for contrast (IV, oral, or both) is debatable and varies from institution to institution. Oral contrast has not been shown to increase the sensitivity of CT.

CT Findings Include.

- appendiceal dilatation (>6 mm diameter)
- wall thickening (>3 mm) and enhancement
- thickening of the cecal apex: cecal bar sign, arrowhead sign
- periappendiceal inflammation
  - o fat stranding
  - o thickening of the lateroconal fascia or mesoappendix
  - o extraluminal fluid
  - o phlegmon (inflammatory mass)
  - o abscess
- focal wall nonenhancement representing necrosis (gangrenous appendicitis) and a precursor to perforation

Less specific signs may be associated with appendicitis:

- appendicolith
- periappendiceal reactive nodal enlargement.

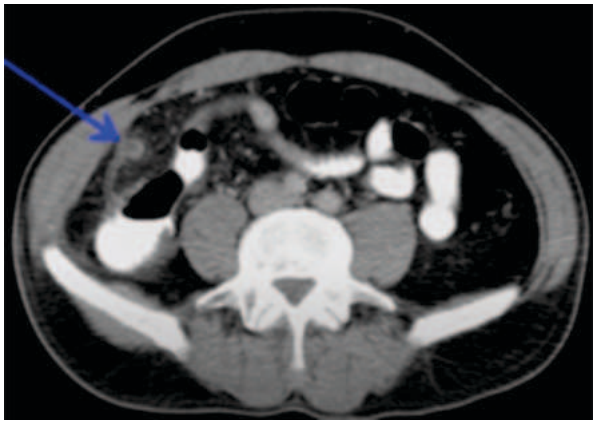


Fig.5: CT Image Showing Appendicitis

OVARIES

The ovaries are the female pelvic reproductive organs that house the ova and are also responsible for the production of sex hormones. They are paired organs located on either side of the uterus within the broad ligament below the uterine (fallopian) tubes. The ovary is within the ovarian fossa, a space that is bound by the external iliac vessels, obliterated umbilical artery, and the ureter. The ovaries are responsible for housing and releasing ova, or eggs, necessary for reproduction. At birth, a female has approximately 1-2 million eggs, but only 300 of these eggs will ever become mature and be released for the purpose of fertilization.

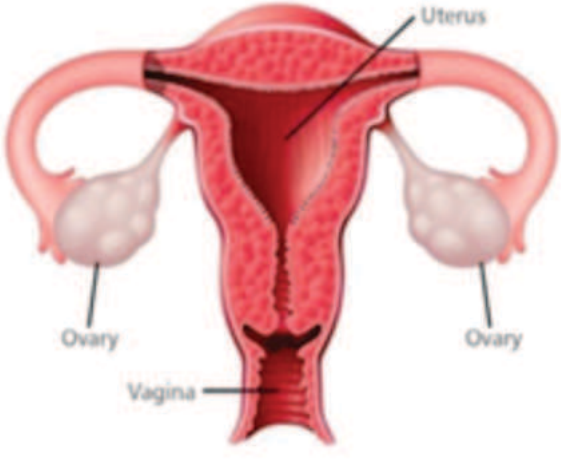


Fig.6: Anatomy Of Ovary

Ovarian Mass

Ovaries can become enlarged (masses or tumors) due to cysts (ovarian and hemorrhagic ovarian cysts), masses (endometriomas), or neoplasms (growths). The vast majority of ovarian neoplasms in girls and young women are not cancerous. Ovarian cysts are usually associated with hormonal stimulation and/or ovulation. Ovarian masses like endometriomas are associated with endometriosis—an inflammatory condition when the glands and stroma of the uterine lining (endometrium) are found outside of the uterine cavity. The cause of both benign and malignant neoplasm is uncertain.

Clinical Presentation

The type, size, and location of the mass or tumor will determine if the patient experiences symptoms. If present, more common symptoms include:

- Fullness
- Pain
- Bloating
- Early satiety
- Urinary and bowel changes
- Menstrual irregularities

If the mass is large enough, particularly in younger patients, the mass may be felt or seen as a lower abdominal bulge.

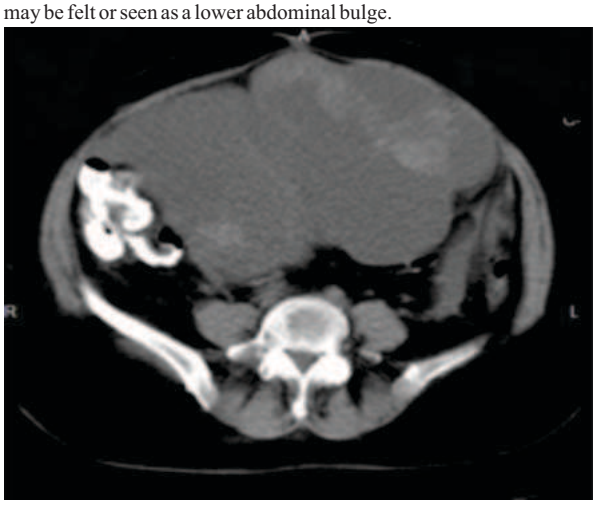


Fig.7: CT Image Showing Ovarian Mass

Aim and Objectives

Aim

To standardise multiphase CECT studies of the abdomen based on the clinical indications for appendicitis, ovarian masses and HCC, thereby optimizing the radiation dose delivered to the patient.

OBJECTIVES

- To analyze the CT abdomen multiphase scan protocols for appendicitis, HCC and ovarian masses and to tailor make the protocol justifiably based on the clinical indications.
- To determine the percentage dose reduction to the revised and justified protocol.

TECHNICAL SPECIFICATIONS OF CT SCANNERS			
1.	MAKE	GE	PHILIPS
2.	MODEL	Revolution Evo	Brilliance -16
3.	NO.OF SLICES	128-slice	16-slice
4.	SLICE THICKNESS	0.625mm	0.75mm, 1.5mm
5.	DETECTOR MATERIAL	HILIGHT SCINTILLATOR	GADOLINIUM OXYSULPHIDE
6.	DETECTOR TYPE	Matrix	Hybrid
7.	DETECTOR WIDTH	40mm	12mm
8.	IMAGE RECONSTRUCTION ALGORITHM	ASiR-V	FILTER BACK PROJECTION
9.	LEAST GANTRY ROTATION TIME	0.35s	0.4s
10.	PITCH	0.5625, 09375, 1.375	0.2 to 1.7

11.	kV RANGE	80-140	90-140
12.	MAXIMUM mA	600	500

Methodology

- **Type of the Study:** Retrospective
- **Sample Size:** Appendicitis-113, HCC- 124, Ovarian masses-34
- **Period of the Study:** March 2021-May 2021
- **Study Venue:** Department of Radiology and Imaging sciences, Sri Ramachandra Institute of Higher Education and Research

Inclusion Criteria

- Patients referred to CECT Abdomen for Appendicitis, Ovarian mass and Hepatocellular Carcinoma.

Exclusion Criteria:

- Patients who are allergic to contrast media

Patients who have undergone CECT ABDOMEN get screened in the department of radiology imaging and sciences. The patient gets an appointment along with pre procedural instructions such as fasting for 4-6 hours , to report with renal function test values (Creatinine , BUN values to be within normal limits) and incase of diabetic patients, to stop metformin one day prior to the procedure.

On the day of examination, the requisition form collected from the patient and their UHID is verified. The procedure is explained to the patient followed by which the informed written consent is obtained. The clinical history of the patient, previous surgery, allergic reactions to any medications enquired and recorded in patient data form. The patient is secured with a proper IV line for injection of contrast media intravenously. Then the patient gets positioned on the CT examination table in supine with feet first orientation. Breath-hold instructions are given to the patient and rehearsed before starting the examination.

The CECT abdomen protocol along with appropriate scan parameters is selected. For a contrast study smart prep technique is activated in GE revolution Evo 128 Slice CT scanner to chase the uniform flow of contrast to the region of interest, a similar technique known as bolus tracking is activated in Philips brilliance 16 slice CT scanner. On the whole the contrast study of abdomen consists of three phases namely arterial phase which will be acquired after 18s, venous phase after 60s, and delayed phase after 3-5mins. Finally the patient is instructed to drink plenty of water for the wash out of the administered contrast.

Retrospectively image data of the patients who have undergone CECT ABDOMEN for clinical indications such as APPENDICITIS, OVARIAN MASSES and HEPATOCELLULAR CARCINOMA are assessed to ascertain the appropriate contrast phase study needed. The result of the assessment will be used for standardizing the protocol for the clinical indications: APPENDICITIS, OVARIAN MASSES and HEPATOCELLULAR CARCINOMA.

The image data is also assessed for finding the scope of reduction in the scan coverage for the appropriate contrast phase study. Such reduction will help in optimizing the radiation dose to the patient.

- **Non-Contrast Study-** Helpful in detecting calcifications, fat in tumors, fat-stranding as seen in inflammation like appendicitis, diverticulitis, omental infarction etc.
- **Early Arterial Phase -** 15-20 sec p.i. or immediately after bolustracking. This is the phase when the contrast is still in the arteries and has not enhanced the organs and other soft tissues.
- **Late Arterial Phase -** 35-40 sec p.i. or 15-20 sec after bolus tracking. Sometimes also called "arterial phase" or "early venous portal phase", because some enhancement of the portal vein can be seen. All structures that get their bloodsupply from the arteries will show optimal enhancement.
- **Hepatic Or Late Portal Phase -** 70-80 sec p.i. or 50-60 sec after bolustracking. Although hepatic phase is the most accurate term, most people use the term "late portal phase". In this phase the liver parenchyma enhances through bloodsupply by the portal vein and you should see already some enhancement of the hepatic veins.
- **Delayed Phase -** 6-10 minutes p.i. or 6-10 minutes after bolus tracking. Sometimes called "wash out phase" or "equilibrium phase". There is wash out of contrast in all abdominal structures except for fibrotic tissue, because fibrotic tissue has a poor late wash out and will become relatively dense compared to normal tissue.

Factors Influencing CT Radiation Dose:

The scan parameters that significantly influences the radiation dose are

- Exposure factors (kVp, mA and s)
- Pitch
- Scan length

Apart from the above mentioned factors, in contrast CT, proper justification for multi-phase study is mandatory.

Data Collection: A detailed clinical history and data which includes

- Patient's name
- Unique ID
- Age
- Gender
- Study
- Number of phases
- Individual dose length product for each phase
- Total Dose length product
- The final radiological impression were collected for all the patients and entered in a specifically designed format.

Total Amount Of Contrast:

1.2 Ml Per Kg Of Body Weight At The Rate Of 3 To 4 Ml Per Second.

- *Iohexol (Omnipaque - 300 mgI/ml)*
- *Iodixanol (Visipaque – 320 mgI/ml*

Scan Protocol:

PARAMETERS	PHILIPS BRILLIANCE 16 SLICE
SCOUT	SINGLE (AP)
SCAN TYPE	HELICAL
PATIENT ORIENTATION	FEET FIRST
ACQUISITION	2mm
RECONSTRUCTION	0.75mm
DETECTOR COVERAGE	24mm
PITCH FACTOR	0.983:1
ROTATION TIME	0.5 s
kV/mAs	120kV/200mAs
COVERAGE SPEED	45mm/s
SFOV	LARGE

PARAMETERS	GE REVOLUTION EVO 128 SLICE
SCOUT	DUAL (AP&LAT)
SCAN TYPE	HELICAL
PATIENT ORIENTATION	FEET FIRST
ACQUISITION	5.0mm
RECONSTRUCTION	0.625mm
DETECTOR COVERAGE	40mm
PITCH FACTOR	0.984:1
ROTATION TIME	0.5 s
kV/mAs	120kV/150mAs
SFOV	LARGE

Retrospectively, the dose data of CECT abdomen referred for Appendicitis, ovarian masses and HCC are collected and tabulated.

Dose Analysis

DLP were calculated by using the formula DLP = (CTDIvol) X Scan length

Effective Dose is calculated by taking the product of Total DLP and the k-factor for abdomen (0.015 mSv $mGy^{-1}.cm^{-1}$)

One of the following combinations shall be selected depending up on the clinical indication.

- Non-contrast + Single phase CECT
- Non-contrast + Dual phase CECT
- Non-contrast + Triple phase CECT

If Non-contrast with all three phases is done, the necessity of each phase for a particular clinical indication is to be analysed and then only the required phases are to be done to optimize the patient radiation dose.

For eg: acute appendicitis

Total Delivered Effective Dose = Total Effective Dose (NC + Arterial + Venous + Delayed)

Total Effective Dose (clinically indicated) = Total Effective Dose (NC + Venous) Arterial & delayed (not required)

%Dose reduction =

Effective Dose (NC+all 3phases) – Effective Dose (Indicated) x100
Effective Dose (NC + all 3phases)

DISCUSSION

CT is a modality known for delivering very high dose to the patients, so dose reduction is a major concern. Every possible step has to be taken in optimizing the patient dose. Reducing dose is possible with reduced exposure parameters such as kV, mA & s, decreasing scan coverage, increasing pitch and limiting multi-phase study to what is necessary for the clinical indication.

Out of the above mentioned options, avoiding unnecessary phase study during Contrast enhanced CT study drastically reduces dose ranging from 25% to 75%. Keeping this in mind, our study analyses the need for the appropriate phase indicated for the particular clinical condition.

Standardisation Of CECT Abdomen Protocol For Appendicitis:

We have retrospectively taken the CECT abdomen having a scheme of Non-contrast + Arterial + Venous + Delayed phase studies. The cases reported to have been diagnosed with appendicitis are segregated and analyzed for the need of any revision in the scheme. After referring to many literatures and after discussing with a team of radiologists, it was suggested that CECT study for appendicitis actually needs only Non-contrast and Venous phase to be executed instead of Non-contrast + Arterial + Venous + Delayed phase studies. If the revised scheme is chosen for exposure, the effective dose received by the patients will get reduced to nearly half.

As per the study carried out for 113 CECT abdomen patients with complaints of abdominal pain and diagnosed with appendicitis, there was nearly 50% dose reduction observed.

CT Dose Data of protocol for Appendicitis						
Scheme	Total DLP (mGy.cm)			Effective Dose (mSv)		
	Min.	Max.	Mean	Min.	Max.	Mean
NC+A+V+D	681.8	6099.1	2652.2667	10.227	91.45	39.78
NC+V	334	3143.42	1330.462	5.01	47.1513	19.95
% Dose reduction = [39.78 -19.95 / 39.78] x100 = 49.85%						

Even though ultrasonography is considered to be the modality of choice for diagnosing appendicitis, CT scan has proven to be more sensitive because in CT image, the retrocaecal position can be well demonstrated; obesity and bowel gas are not limitations.

In CT for diagnosing appendicitis, Non-contrast study is carried out to check the appendiceal dilatation, appendicolith, and also wall-thickening. Venous phase of contrast study is performed in order to rule-out mucosal hyperenhancement. The Arterial and Delayed phases of contrast studies do not yield any additional diagnostic detail with regard to the appendix. So, these two phases shall be omitted while doing CT scan for appendicitis.

Standardisation Of CECT Abdomen Protocol For Ovarian Masses:

We have retrospectively taken the CECT abdomen having a scheme of Non-contrast + Arterial + Venous + Delayed phase studies. The cases reported to have been diagnosed with ovarian masses are segregated and analyzed for the need of any revision in the scheme. After referring to much literature and after discussing with a team of radiologists, it was suggested that CECT study for ovarian masses actually needs only Non-contrast and Venous phase to be executed instead of Non-contrast + Arterial + Venous + Delayed phase studies. If the revised scheme is chosen for exposure, the effective dose received by the patients will get reduced to nearly half. As per the study carried out for 34 CECT abdomen patients with complaints of abdominal pain / abdominal distension / adnexal mass and diagnosed with ovarian masses, there was nearly 50% dose reduction observed.

CT Dose Data of protocol for Ovarian masses						
Scheme	Total DLP (mGy.cm)			Effective Dose (mSv)		
	Min.	Max.	Mean	Min.	Max.	Mean
NC+A+V+D	1181.8	3784.6	2844.60	17.7	56.769	42.669
NC+V	778.94	2088.6	1454.46	11.6841	31.329	21.8169
% Dose reduction = [42.669 – 21.8169/42.669] x100 = 49.87%						

In CT for diagnosing ovarian masses, Non-contrast study is carried out to rule out hemorrhagic content in the mass .Venous phase of contrast study are carried out for enhancing the septa and enhancing solid components of the mass. The Arterial and Delayed phases of contrast studies do not yield any additional diagnostic detail with regard to the ovarian masses. So, these two phases shall be omitted while doing CT scan for ovarian masses.

Standardisation Of CECT Abdomen Protocol For Hepatocellular Carcinoma (HCC):

We have retrospectively taken the CECT abdomen having a scheme of Non-contrast + Arterial + Venous + Delayed phase studies. The cases reported to have been diagnosed with HCC are segregated and analyzed for the need of any revision in the scheme. After referring to many literature and after discussing with a team of radiologists, it was suggested that the executed CECT studies consisting of Non-contrast + Arterial phase + Venous phase + Delayed phase are all justified for the assessment of HCC.

As per the study carried out for 124 CECT abdomen patients with complains of abdominal pain / liver mass / liver cirrhosis and diagnosed with HCC, the effective dose ranges from 69.748mSv to 20.600mSv with an average of 44.333 mSv.

CT Dose Data of protocol for Hepatocellular carcinoma						
Scheme	Total DLP (mGy.cm)			Effective Dose (mSv)		
	Min.	Max.	Mean	Min.	Max.	Mean
NC+A+V+D	1373.37	4649.9	2962.159	20.600	69.748	44.333

In CT for HCC, enhancement pattern forms the key aspect for diagnosis. During arterial phase, vivid enhancement of the mass is observed. During porto-venous phase and the following delayed phase washout is noticed. Delayed phase helps to differentiate HCC from cholangiocarcinoma. As all the 3 phases of contrast study have significance in interpreting HCC, carrying out all the phases is justified.

CONCLUSION

Keeping radiation dose as low as reasonably achievable (ALARA) is the guiding principle for a medically indicated CT examination. Even though many techniques and strategies are available for radiation dose reduction in CT scan, justification and optimal protocol selection of the CT examination represents the most critical aspect of dose reduction. When the radiation dose per each examination is reduced, the associated risk is also reduced, resulting in further improvement of the benefit/risk ratio.

With regard to CT radiation dose levels, radiologists can successfully implement a system of continuous process improvement by determining baseline dose levels for various CT study types at their institutions, setting goals for dose reduction, modifying or tailor making the CT protocols in accordance to the clinical indication, and implementing the changes incrementally and iteratively to minimize adverse effects.

In our study, for diagnosing Appendicitis / Ovarian masses, if Non-contrast study along with Venous phase of contrast study are carried out instead of Non-contrast study along with Arterial, Venous and Delayed phases of contrast studies, nearly 50% dose reduction is expected. But in the case of HCC, there is a need to carry out Non-contrast study along with Arterial, Venous and Delayed phases of contrast studies. The justification for carrying out each phase of the contrast study is to be analyzed by the Radiologist by going through the C.T. request prior to the patient scan and then the optimal protocol instructions are to be given to the CT technologist.

Highest radiation dose reduction is possible by limiting phase(s) in the multi-phase CECT studies to what is necessary. Standardization of CT scan protocol for some of the most common clinical indications will be helpful in ensuring optimal usage of radiation on patients.

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