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THORACO-ABDOMINAL TRIPHASIC CT IN ONCOLOGIC FOLLOW-UP: ASSESSMENT AND ADVANTAGES OF "LOW DOSE" PROTOCOL

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Abstract. *The objective was to compare the contrast enhanced computed tomography (CT) "LOW DOSE" protocol for thoraco-abdominal scans, with the standard CT protocol for oncologic follow up. We analyzed these two different imaging techniques and the overall radiation dose in order to determine benefits in terms of diagnosis. We included 50 patients where oncologic follow up included a triphasic thoraco-abdominal CT for staging of liver disease. Eligibility criteria were the medical indication for a contrast-enhanced thoraco-abdominal CT as part of an oncologic follow up (breast cancer, hepatocarcinoma, neuroendocrine tumors, kidney cancer and prostatic cancer) and the availability of previous enhanced CT scans performed over the past year of follow up. The LOW DOSE protocol for triphasic CT in oncologic follow up permits saving of effective dose up to 50% (27% on average) for each scan and an overall saving of up to 40% (15% on average) for complete procedure in the normal BMI group. The LOW DOSE protocol was also effective in the diagnosis of thromboembolic disease. All the scans from the LOW DOSE CT protocol were analyzed by radiologists, all with at least 10 years of experience, unaware of the introduction of the protocol – there were no reported differences or difficulties in diagnosis compared to the standard CT protocol.*

Key words: *Effective dose, Helical Computed Tomography (CT), oncology, radiation dose reduction, triphasic technique*

1. Introduction

Oncologic follow-up often requires close monitoring with imaging, whereby patients are exposed to an overall high radiation dose. As a result, it seems important not only to be aware of modern technologies, but also to give consideration to the radiation dose delivered to patients.

2. Materials and methods

2.1 Study population

Eligibility criteria were the medical indication for a contrast-enhanced thoraco-abdominal CT as part of an oncologic follow up (breast cancer, hepatocarcinoma, neuroendocrine tumors, kidney cancer and prostatic cancer) and the availability of previous enhanced CT (computed tomography) scans performed over the past year of follow up.

An analysis of prospectively collected data was performed from January to May 2017 in 50 patients where oncologic follow up included a triphasic thoraco-abdominal CT for staging of liver disease.

All patients were divided into two groups according to a normal (15-30 kg/m2) or high (> 30 kg/m2) body mass index (BMI).

2.2 Image technique

All scans were performed with 128 x 2-channel multidetector CT system dual source (SOMATOM Definition Flash, Siemens medical solution).

2.3 Standard CT

Beam collimation, 32x1.2. Pitch, 0.6 for abdomen and 1.2 for thorax. Rotation time, 0.5 s. Software: Care Dose; Care kV. The Scan direction is top-bottom. Reconstruction: Kernel B40 for abdomen; Kernel B30 for mediastinum; Kernel B70 for lung.

The patient was feet-first supine on the CT bed, they were connected to the Contrast Medium automatic injector.

The scan started with the bottom topogram from lung apices to femoral diaphysis. The first phase was superior abdomen precontrast. Then, bolus tracking pre-monitoring at thoraco-abdomen passage with ROI in aorta was considered independent of respiratory movements. Monitoring set at 110 HU deleted by 13 seconds from the start of injection. Auto-start on overcoming the threshold. The arterial phase (copied

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from precontrast phase) delayed by 12 seconds from auto-start. Then, the thorax phase after 13 seconds. The hepatic venous phase delayed for 35 seconds from the thorax phase. The last phase on all abdomen was after 90 seconds.

The contrast Medium used was Ultravist 370 mg/ml. It was injected via the anterocubital vein in 1.2 mL/kg. The contrast medium technique consisted of double bolus: saline solution follows the contrast medium.

2.4 Low dose CT

Beam collimation, 32x1.2. Pitch, 0.6 for all scans. Rotation time, 0.5 s. Software: Care Dose; Care kV. Reconstruction: Kernel B40 for abdomen; Kernel B30 for mediastinum; Kernel B70 for lung.

The patients were feet-first supine on CT bed, and they were connected to the Contrast Medium automatic injector.

The scan started with bottom topogram from lung apices to femoral diaphysis. The first phase was superior abdomen precontrast. Then the bolus tracking pre-monitoring was performed at the thoraco-abdomen passage with ROI in aorta. Monitoring was set at 95 HU with 11 seconds of retardation from the injection. Auto-start over threshold. The arterial phase was caudo-cranial direction, from inferior renal pole to lung apices. The hepatic venous phase was after 40 seconds from the arterial phase. The last phase on all abdomen was after 120 seconds.

The contrast Medium was Ultravist 370 mg/ml. It was injected via the anterocubital vein in 1.2 mL/kg. The contrast medium technique consisted of double injection: salina solution follows contrast medium.

2.5 Difference between Standard and Low dose CT

The most important difference between the standard CT and low dose CT was the scan direction of the arterial phase and the thorax phase.

Standard CT scans two different volumes in cranio-caudal direction (liver and lung). Low dose CT scans just one unique volume (liver and lung together) in the caudo-cranial direction.

2.6 Comparing contrast medium injection

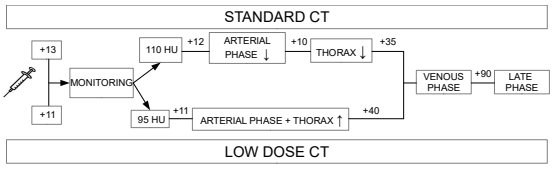

Figure 1. Thriphasic study acquisition in standard CT and low dose CT

2.7 Radiation dose estimates

We recorded each CT dose index per volume (CTDIvol) and dose length product (DLP) value, based on dose reports from the pictures archiving and communication system (PACS), for all phases. The effective dose should be calculated by multiplying the DLP value by the normalized value of the conversion factor (EDLP).

In our study, there were two anatomical regions with two different EDLP (k=0.014 for thorax and k=0.015 for abdomen) and the caudo-cranial thoraco-abdomen scan provided a unique DLP value despite the existence of two different regions. To obtain an estimated value to the conversion we used EDLP=0.0145, the average between EDLP for thorax and abdomen.

3. RESULTS

3.1 Radiation dose estimates

We classified two types of comparison: Total body scan, which analyzed all CT exams (with all phases); and Single scan, which only analyzed the difference between the caudo-cranial and the cranio-caudal thoraco-abdomen phase.

The table with the dosimetric references of the two CT methods described is shown below. The values of the effective dose E (mSv) were calculated according to what was described in the previous paragraph. It is emphasized that the comparison between the CT methods occurred on the same patients.

3.2 Total body

Table 1. Effective dose (E) and dose saving rate for the entire Total Body CT for 15<BMI<30

15<BMI<30

Patient	BMI (kg/m²)	DLP old	DLP new	E old (mSv)	E new (mSv)	%
2	17.4	1002	732	14.5	10.6	26.9
3	19.1	1338	1020	19.4	14.8	19.4
5	20.2	1406	850	20.4	12.3	39.5
25	13.7	792	774	11.5	11.2	2.3
28	20.6	1286	883	18.7	12.1	35.2
38	19.5	991	973	14.4	14.1	1.8
40	19.8	1027	983	14.9	14.3	4.3
42	20.8	1344	1138	19.5	16.5	15.3
45	19.6	923	821	13.4	11.9	11.1
48	19.6	1163	1009	16.9	14.6	13.2
51	19.6	1058	976	15.3	14.2	7.8
53	19.8	1597	1167	23.2	16.9	27.0
1	23.1	1028	925	15.0	13.4	10.0
8	24.7	1671	1609	24.2	23.3	3.7
9	25.0	1474	1122	21.4	16.3	23.9
14	24.7	1295	1242	18.8	18.0	4.1
20	21.4	1128	1085	16.4	15.8	3.8
22	22.5	1676	1377	24.3	20.0	17.8
23	23.6	1352	1109	19.6	16.1	18.0
33	24.1	1411	1033	20.5	15.0	26.8
34	22.7	1389	1192	20.1	17.3	14.2

Patient	BMI (kg/m²)	DLP old	DLP new	E old (mSv)	E new (mSv)	%
37	24.7	2382	2157	34.5	31.3	9.5
39	21.7	1401	1192	20.3	17.3	15.0
43	22.1	1112	896	16.1	13.0	19.4
44	23.8	1475	1363	21.4	19.8	7.6
47	23.6	1403	1344	20.3	19.5	4.2
54	23.5	1526	1178	22.1	17.1	22.1
6	26.3	1379	1305	20.0	18.9	5.4
7	26.1	1701	1531	24.7	22.2	10.0
16	25.8	1628	1302	23.6	18.9	20.0
19	28.9	1790	1546	26.0	22.4	13.6
21	25.7	1587	1417	23.0	20.6	10.7
29	27.3	1902	1676	27.6	24.3	11.9
30	27.0	1693	1388	24.6	20.1	18.0
31	25.0	1311	1181	19.0	17.1	9.9
35	26.8	1516	1296	22.0	18.8	14.5
41	27.0	1403	1016	20.3	14.7	27.6
46	29.7	1483	1157	21.5	16.8	22.0
49	25.0	1319	1101	19.1	16.0	16.5
52	28.0	1586	1397	23.0	20.3	11.9
AVG		**1398**	**1186**	**20.3**	**17.2**	**15.2 %**

Table 2. Effective dose (E) and dose saving rate for the entire Total Body CT for BMI>30

BMI>30

Patient	BMI (kg/m2)	DLP old	DLP new	E old (mSv)	E new (mSv)	%
4	35.7	3393	2945	49.2	42.7	13.2
10	32.4	2653	2287	38.5	33.2	13.8
27	32.9	2999	2211	43.5	32.1	26.3
31	32.5	2000	1471	29.0	21.3	26.5
55	38.0	5360	2795	77.7	40.5	47.9
56	30.4	1840	1571	26.7	22.8	14.6
AVG		**3040**	**2213**	**44.1**	**32.1**	**27.2 %**

Below is a histogram showing the effective dose E (mSv) between the two compared protocols based on the BMI classes.

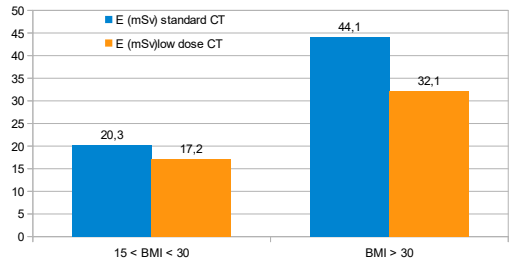

Figure 2. Effective dose E (mSv) for standard CT (blue) and low dose CT (orange)

3.3 Single scan

Table 3. Effective dose (E) and percentage of dose saving in thoraco-abdomen scan for 15<BMI<30

15<BMI<30

Patient	BMI (kg/m2)	DLP A+T	DLP 1 scan	E A+T (mSv)	E 1 scan (mSv)	%
2	17.4	114+143	188	3.7	2.7	27.1
3	19.1	189+167	219	5.6	3.2	38.4
5	20.2	305+167	242	6.8	3.5	48.2
25	13.9	118+103	193	3.2	2.8	12.5
28	20.6	193+221	207	6.0	3.0	50.1
38	19.5	163+149	254	4.5	3.7	18.5
40	19.8	164+171	272	4.9	3.9	18.9
42	20.8	181+213	304	5.7	4.4	23.1
45	19.6	130+145	243	4.0	3.5	11.8
48	19.6	160+185	311	5.0	4.5	10.1
51	19.6	132+179	279	4.5	4.1	10.8
53	19.8	271+204	288	6.9	4.2	39.1
1	23.1	158+165	213	4.7	3.1	34.1
8	24.7	251+269	467	7.6	6.8	10.3
9	25.0	334+222	308	8.0	4.5	44.2
14	24.7	186+197	313	5.6	4.5	18.4
20	21.4	180+168	288	5.0	4.2	17.1
22	22.5	241+222	330	6.7	4.8	28.6
23	23.7	199+210	307	5.9	4.5	25.0
33	24.1	194+217	269	6.0	3.9	34.7
34	22.7	201+212	281	6.0	4.1	32.0
37	24.7	586+276	617	12.1	9.0	26.0
39	21.7	212+165	268	5.4	3.9	28.6
43	22.0	165+179	234	5.0	3.4	32.8
44	23.8	238+223	400	6.7	5.8	13.1
47	23.6	137+171	269	4.5	3.9	13.0
54	23.5	300+153	288	6.5	4.2	35.7
6	26.3	277+221	379	7.2	5.5	23.6
7	26.1	264+264	404	7.7	5.9	23.5
16	25.8	259+250	369	7.4	5.4	27.5
19	28.9	276+268	384	7.9	5.6	29.4
21	25.7	257+246	366	7.3	5.3	27.2
29	27.9	250+213	372	6.7	5.4	19.4
30	27.0	249+250	350	7.2	5.1	29.9
31	25.0	210+177	287	5.6	4.2	25.6
35	26.8	254+219	334	6.8	4.8	29.2
41	27.0	299+234	387	7.7	5.5	28.8
46	29.7	236+257	326	7.2	4.7	34.0
49	25.0	308+165	284	6.8	4.1	39.3
52	28.0	227+201	335	6.2	4.9	21.6
AVG				**6.2**	**4.5**	**27.3 %**

Table 4. Effective dose (E) and percentage of dose savings in thoraco-abdomen scans for BMI> 30

BMI>30

Patient	BMI (kg/m2)	DLP A+T	DLP 1 scan	E A+T (mSv)	E 1 scan (mSv)	%
4	35.7	603+524	769	16.3	11.2	31.6
10	32.4	490+338	607	11.9	8.8	26.2
27	32.9	554+402	579	13.8	8.4	39.1
32	32.5	360+304	357	9.6	5.2	46.1
55	38.0	1080+667	686	25.1	10.0	60.4
56	30.4	274+230	340	7.3	4.9	32.3
AVG				**14.0**	**8.1**	**42.4%**

Below is a histogram showing the effective dose E (mSv) between the two compared protocols based on the BMI classes.

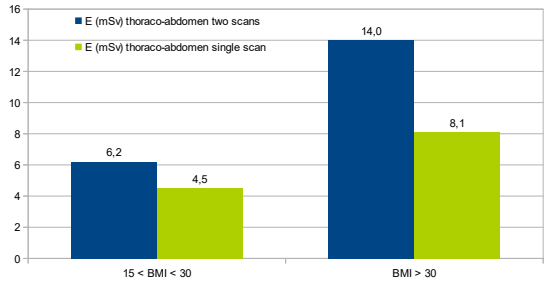

Figure 3. Effective Dose E (mSv) for thoraco-abdominal two scans for standard CT (blue) and thoraco-abdominal single scan for low dose CT (green)

3.4 Image analysis

The images obtained with the low dose CT were reported by radiologists with at least 10 years of experience without knowledge of the introduction of the low dose CT scan (one blind): the radiologists did not report any differences and/or diagnostic difficulties.

3.5 Thromboembolic disease

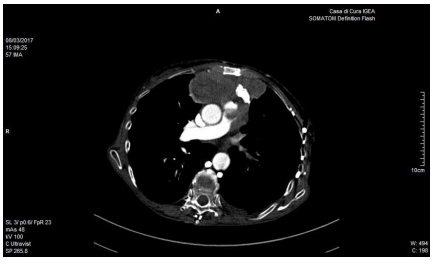

Figure 4. Mediastinal mass infiltrating pulmonary artery

The caudo-cranial scan was obtained to acquire all thoraco-abdominal volume in ±12 seconds. The delay from the injection of 11 seconds allows the study of thorax volume at the fortieth second, ideal to study both the parenchyma and mediastinum (M+) and the arterial vascular tree (TPE).

4. Conclusion

The Low Dose protocol for triphasic CT in oncologic follow up permits saving of effective dose of up to 50% (27% on average) for each scan and an overall saving of up to 40% (15% on average) for the complete procedure in the normal BMI group. The Low Dose protocol is also efficient in the diagnosis of the thromboembolic disease.

All the scans from the Low Dose CT protocol were analyzed by radiologists, all with at least 10 years of experience, unaware of the introduction of the protocol. There were no reports of any differences or difficulties in diagnosis compared to the standard CT protocol.

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