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CLINICAL INVESTIGATION RADIATION PROTECTION

Radiation Exposure During Transarterial Chemoembolization: Angio-CT Versus Cone-Beam CT

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Abstract

Introduction Cone-beam computed tomography (CBCT) has been developed to improve reliability of many interventional radiology (IR) procedures performed with Angio system, such as transarterial chemoembolization (TACE). Angio-CT has emerged as a new imaging technology that combines a CT scanner with an Angio system in the same IR suite. The purpose of our study was to compare Angio system with CBCT capability and Angio-CT in terms of patient radiation exposure during TACE procedures.

Materials and Methods Consecutive TACE procedures performed between January 2016 and September 2017 with the two imaging modalities (Artis Zeego defining the CBCT group and Infinix-i 4D-CT defining the Angio-CT group) were reviewed. TACE and patient's characteristics and patient radiation exposure parameters were collected. Dose-area products (DAP) and dose-length products (DLP) were converted into effective doses (ED) using conversion factors. Accuracy of tumor targeting and response was retrospectively assessed.

Results A total of 114 TACE procedures in 96 patients were included with 57 procedures in each group. The total ED in the Angio-CT group was 2.5 times lower than that in the CBCT group (median 15.4 vs. 39.2 mSv, $p < 0.001$). Both 2D ED and 3D ED were lower in the Angio-CT group than in the CBCT group (5.1 vs. 20 mSv, $p < 0.001$, and 7.4 vs. 17.9 mSv, $p < 0.001$, respectively). There was no significant difference neither in terms of classes of tumor targeting ($p = 0.509$) nor in terms of classes of tumor response ($p = 0.070$) between both groups.

Conclusion Angio-CT provides significant decrease in patient effective dose during TACE procedures compared to Angio system with CBCT.

Keywords Chemoembolization · Therapeutic · Cone-beam computed tomography · Interventional radiology · Liver · Radiation exposure

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Introduction

Transarterial chemoembolization (TACE) is one of the most performed endovascular interventional radiology (IR) procedures. It has been endorsed by American and European guidelines for the treatment of hepatocellular carcinoma (HCC) and is currently the standard of care for patients with intermediate stage HCC (Barcelona clinic liver cancer (BCLC) stage B) [1, 2]. Besides primary

cancer, TACE can also be used to treat liver metastases, especially neuroendocrine tumors [3, 4].

In general, TACE procedures are performed in a dedicated IR suite. Most modern IR suites are equipped with flat panel detector (FPD) Angio system enabling fluoroscopy and digital subtraction angiography (DSA) acquisitions. The two-dimensional (2D) nature of these imaging guidance techniques explains a lower sensitivity for localizing tumors and detecting tumor-feeding vessels compared to cone-beam CT (CBCT) [5, 6]. CBCT technology is based on the generation of a three-dimensional (3D) volumetric dataset from multiple 2D projections acquired during a single Angio system rotational acquisition [7, 8]. Combining real-time 2D imaging and CT-like images in the IR suite has been a considerable step forward in improving the reliability of many IR procedures [9]. Although the proven clinical value of CBCT, the technique also has several limitations such as a reduced signal-to-noise ratio, a small field-of-view and the literature reported a negative impact on patient radiation exposure [10–12].

Angio-CT has emerged as a new imaging technology that combines a CT scanner with a flat panel Angio system in the same IR suite. The first Angio-CT version was developed in Japan in the 1990s [13]; and since then, Angio-CT technology has steadily improved thanks to the tremendous progress made in both multidetector CT and Angio systems. Very few studies have reported TACE procedures using the image guidance of an Angio-CT system [14, 15]. Beyond price issues, one reason that could have delayed the widespread use of such an IR suite is the preconceived idea of patient radiation overexposure induced by the combination of two imaging modalities both delivering radiation [16]. The recent introduction of radiation exposure reference levels (RL) [17, 18] gives the opportunity to objectively evaluate the impact of Angio-CT on patient radiation exposure.

The purpose of our study was to compare Angio system with CBCT capability and Angio-CT in terms of patient radiation exposure during TACE procedures.

Materials and Methods

Study Design

This study is based on a review of consecutive TACE procedures performed between January 2016 to June 2016 and from April to September 2017 in our department with two different imaging modalities, defining two study groups. From January to June 2016, TACE procedures were performed in our IR suite equipped with a floor-based flat panel Angio system with CBCT capability (Artis Zeego, Siemens Healthineers, Erlangen, Germany) defining the CBCT group. From April to September 2017, after the changeover of our interventional suite, TACE procedures were performed using an Angio-CT suite combining a flat panel Angio system and a multidetector CT scanner (Infinix-i 4D-CT, Canon Medical Systems, Otawara, Japan), defining the Angio-CT group.

All TACE sessions were performed on adult patients with HCC or neuroendocrine liver metastases after multidisciplinary tumor board approval. The institutional ethics review board approved the design of the study and the retrospective analysis of the data (NCT: 03698643), which were evaluated anonymously. All patients gave written informed consent.

TACE Procedures

Ten senior radiologists performed TACE in our center during the study period, following a standardized protocol. For all procedures, the contrast medium iobitridol 350 mg iodine/mL (Xenetix, Guerbet, Aulnay-sous-Bois, France) was used. Procedures were performed under local or general anesthesia. Portal vessels patency was assessed using ultrasound in the IR suite before every procedure. For all patients, a 5-Fr sheath was introduced through the femoral artery using Seldinger technique [19] and catheterization of the celiac trunk was performed using 5-Fr Simmons catheter. In the CBCT group, celiac trunk DSA was performed to assess the vascular anatomy. The proper hepatic artery was then catheterized using a 2.8 Fr microcatheter. When needed, a CBCT volume was acquired to identify the tumor feeders (see below for further details on DSA and CBCT parameters). In the Angio-CT group, a CT acquisition was performed with a simultaneous contrast medium injection, using the catheter in the celiac trunk, allowing to assess vascular anatomy and to identify tumor feeders (see below for further details on CT parameters). Proper hepatic artery catheterization was achieved using 3D roadmap reconstruction from CT images. Afterward, in both groups, the tip of the catheter was advanced further as selective as possible, defining lobar TACE (catheter positioned in the origin of the left or the right hepatic artery) or superselective TACE (catheter placed beyond), depending on the size, location and feeders of the tumor. Anticancer agent (doxorubicin or idarubicin) was delivered with a slow flow rate through the catheter under fluoroscopic control, combined either with drug-eluting beads (DEB) or with Lipiodol. In the latter case, the embolic agent consisted of gelatin sponge. The embolization was stopped when substasis was achieved. Treatment evaluation was performed either at the end of the procedure (CBCT or CT volume acquisition) or within 1 day after the procedure (CT acquisition).

Patient age, body mass index (BMI), sex, type of tumor(s) (HCC or metastases), lesions distribution (uni or bilobar), number of lesions, TACE technique (lobar or superselective), drug vector (Lipiodol or DEB), anticancer agent (doxorubicin or idarubicin) and type of anesthesia (local or general) were collected for each TACE procedure.

Equipment Characteristics and Acquisition Parameters

CBCT Group (Artis Zeego, Fig. 1A)

This system was installed in our department in November 2009. Equipped with a 30 × 40 cm FPD, this system could perform CBCT by rotating isocentrically around the patient through 200°. The following parameters were used for celiac trunk DSA acquisitions: field of view (FOV): 42 or 48 cm (diagonal), frame rate: 2 or 3 frames per second (fps), volume of contrast medium: 20 mL, flow rate: 4 mL/s, delay: 2 s. When needed, CBCT acquisition was performed with the following parameters: FOV: 48 cm, frame rate: 60 fps, acquisition time: 8 s, volume of contrast medium: 17 mL, flow rate: 1.5 mL/s, delay: 9 s. In case of a control CBCT acquisition, parameters were equal, but without contrast medium injection.

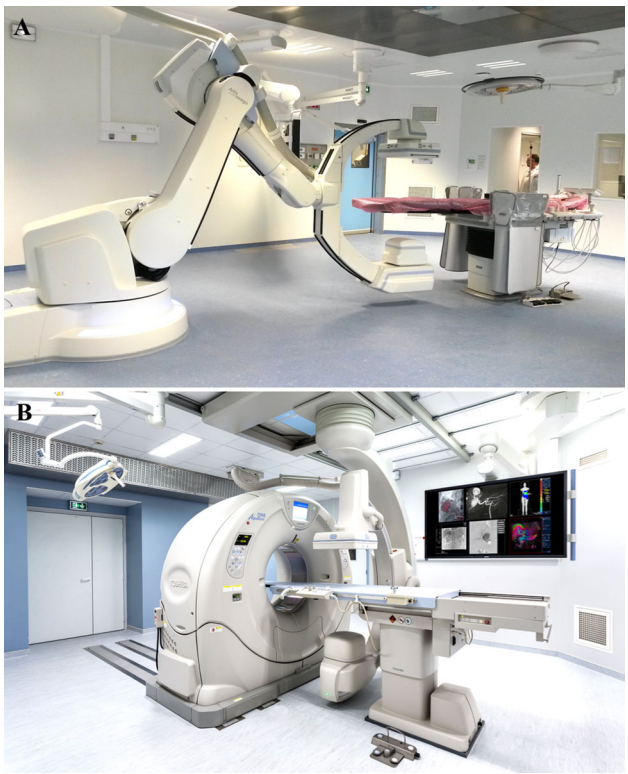

Fig. 1 IR suite equipped with **A** Angio system with CBCT capability (Artis Zeego, Siemens Healthineers); **B** Angio-CT (Infinix-i 4D CT, Canon Medical Systems)

Angio-CT Group (Infinix-i 4D CT, Fig. 1B)

This system was installed in our department in March 2017 and combines a CT scanner equipped with a 320 row detector with a 30 × 40 cm FPD which is supplied with fluoroscopy optimization tools. "Spot fluoroscopy" permits a flexible acentric and asymmetric collimation which can be defined anywhere on the last image hold of the FOV exposed. The integrated adaptive exposure control mechanism decreases the detector input dose proportional to the scatter radiation saved by the collimation applied. "Live zoom" is a numerical zoom that permits anatomical magnification. Up to four different zoom factors (1.2, 1.4, 1.8 and 2.4) can be applied to a selected FOV while keeping the respective detector dose constant. The following parameters were used for CT volume acquisition in the celiac trunk: sequential acquisition (one rotation), total collimation: 320 × 0.5 mm, rotation time: 0.35 s, slice thickness: 0.5 mm, kV: 120, mA: 80-500 with automatic tube current modulation—noise index: 9.5, volume of contrast medium: 26 mL, flow rate: 4 mL/s, delay: 6 s. Control CT scan at the end of the procedure was performed with the same parameters, but without contrast medium injection. An iterative reconstruction algorithm (AIDR 3D Standard) with a convolution filter (FC18) was applied for reconstruction.

Patient Dose Values

For all TACE procedures, fluoroscopy time, number of DSA runs, number of CBCT acquisitions, number of CT acquisitions, air kerma, total dose-area product (DAP), 2D-specific DAP (from fluoroscopy and DSA acquisitions), CBCT-specific DAP (if CBCT was performed), dose-length product (DLP) (if CT was performed) were gathered using a dose archiving and communication system (Dosewatch, GE healthcare, Milwaukee, WI, USA) based on radiation dose structured reports. For treatment evaluation outside the IR suite, an Optima CT660 CT scanner (GE Healthcare) was used with these settings: helical acquisition, collimation: 64 × 0.625 mm, pitch: 1.375, rotation time: 0.7 s, slice thickness: 1.25 mm, kV: 120, mA: 180-400 with automatic tube current modulation—noise index: 18, and DLP was collected. A soft reconstruction kernel with 50% strength of iterative reconstruction algorithm (ASIR) was applied for reconstruction.

Effective doses (ED) were obtained then from DAP and DLP using the following conversion factors. 2D-specific DAP were converted into 2D ED using 0.16 mSv Gy^{-1} - cm^{-2} conversion factor [20]. CBCT-specific DAP were converted into CBCT ED using 0.30 mSv Gy^{-1} cm^{-2} conversion factor [21–23]. DLP were converted into CT

ED using 0.015 mSv mGy^{-1} cm^{-1} conversion factor [24]. 3D ED included CBCT and CT ED, including the treatment evaluation CT outside the IR suite when performed. Total ED included ED of TACE procedure and ED of CT outside the IR suite when performed.

Tumor Targeting Accuracy and Oncological Response

Assessment of the accuracy of tumor targeting and response was retrospectively performed by one radiologist specialized in liver imaging. Tumor targeting on control CBCT or CT was assessed and graded as follows: fully targeted [meaning that all tumor nodule(s) were fully, i.e. 100%, targeted by TACE], partially targeted (some tumor nodules were not targeted or $< 100\%$ tumor volume was targeted) or untargeted (TACE was administered outside any tumor nodule). Tumor response was assessed on follow-up imaging CT or MRI, which was performed 6–8 weeks after the TACE procedure. Tumor response was based on mRECIST criteria [25] and graded as follows: tumor response, stability or progression. Tumor stability or tumor progression defined the absence of objective tumor response.

Statistical Analysis

Chi-square test was applied for qualitative variables comparison (without any correction for multiple testing procedures) and Cochran–Mantel–Haenszel test was applied for adjustment when necessary. The distribution of quantitative variables was assessed using the Shapiro–Wilk test. When variables did not have a normal distribution, non-parametric Wilcoxon test was applied for comparison. A p value of < 0.05 was considered statistically significant. All statistical analyses were performed using SAS University Edition software (SAS Institute, Cary, NC, USA).

Results

TACE Procedures and Patient's Characteristics

A total of 114 TACE procedures in 96 patients were included, 57 in each group (flowchart in Fig. 2). Age, sex, BMI, type of tumor, lesions distribution, number of lesions, TACE technique, drug vector and type of anesthesia did not differ between the two groups. Idarubicin was the most

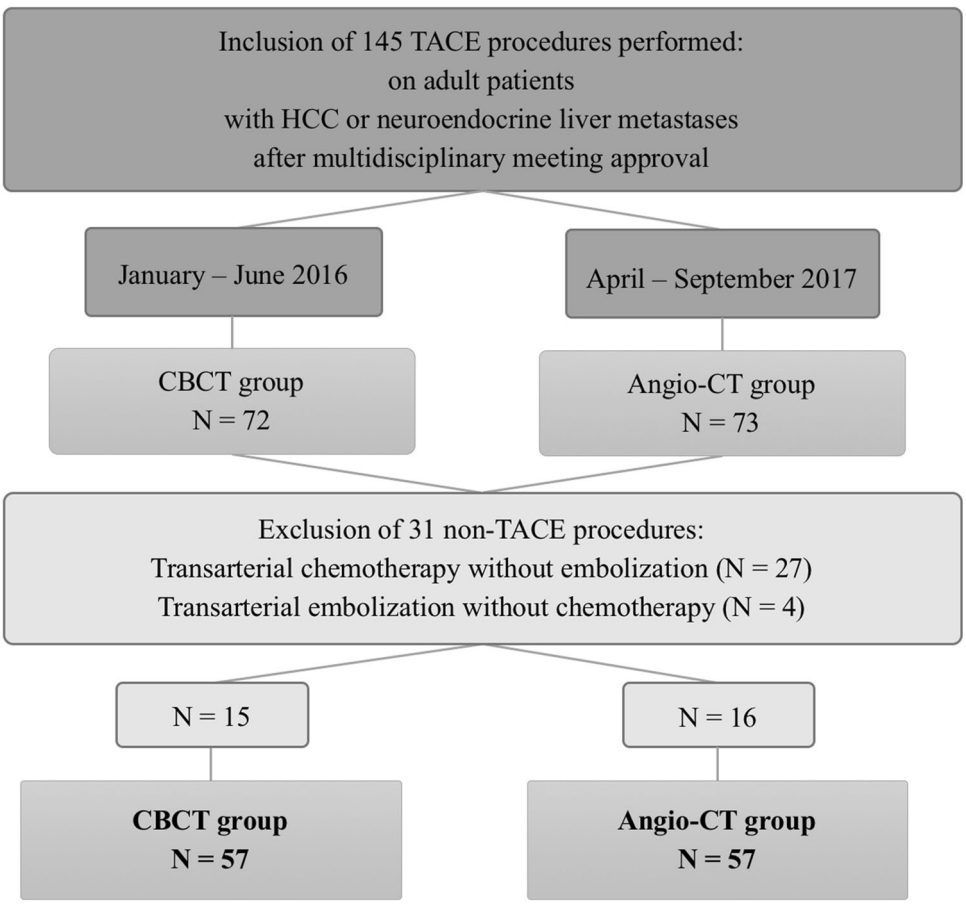

Fig. 2 Flowchart

Table 1 Comparison of baseline characteristics between procedures of the two imaging modalities groups

	Total (n = 114)	CBCT group (n = 57)	Angio-CT group (n = 57)	p value
Age	68 (60–73)	68 (60–73)	69 (62–72)	0.581
Body mass index (kg/m^2)	26.1 (23.0–29.1)	24.9 (22.4–28.4)	27.2 (23.4–29.4)	0.071
Sex				0.635
Male	92 (81%)	47 (82%)	45 (79%)	
Female	22 (19%)	10 (18%)	12 (21%)	
Type of tumor				0.202
HCC	84 (74%)	45 (79%)	39 (68%)	
Metastases	30 (26%)	12 (21%)	18 (32%)	
Lesions distribution				0.129
Unilobar	48 (42%)	28 (49%)	20 (35%)	
Bilobar	66 (58%)	29 (51%)	37 (65%)	
Number of lesions				0.341
1–3	47 (41%)	26 (46%)	21 (37%)	
> 3	67 (59%)	31 (54%)	36 (63%)	
TACE technique				0.053
Superselective	42 (37%)	16 (28%)	26 (46%)	
Lobar	72 (63%)	41 (72%)	31 (54%)	
Drug vector				0.821
Lipiodol	89 (78%)	44 (77%)	45 (79%)	
DEB	25 (22%)	13 (23%)	12 (21%)	
Anticancer agent				0.023
Doxorubicin	48 (42%)	18 (32%)	30 (53%)	
Idarubicin	66 (58%)	39 (68%)	27 (47%)	
Type of anesthesia				0.255
Local	48 (42%)	21 (37%)	27 (47%)	
General	66 (58%)	36 (63%)	30 (53%)	

Qualitative data are expressed as numbers (percentages). Quantitative data are median (interquartile range) because of non-normally distributed variables

HCC hepatocellular carcinoma, *TACE* transarterial chemoembolization, *DEB* drug-eluting beads, *CBCT* cone-beam computed tomography, *CT* computed tomography

used anticancer agent in the CBCT group, while it was doxorubicin in the Angio-CT group (p = 0.023) (Table 1).

Post-procedural CBCT or CT examination was performed in 107 of 114 TACE procedures. When performed, the treatment evaluation imaging technique was mostly CBCT (74%) in the CBCT group and CT during TACE procedure (93%) in the Angio-CT group (Fig. 3).

Patient Radiation Exposure Analysis

Comparison of the dose-related parameters per procedure is shown in Table 2, ED comparison is shown in Fig. 4. The total ED in the Angio-CT group (median 15.4 mSv, IQR 6.8–20.8) was 2.5 times lower than that in the CBCT group (median 39.2 mSv, IQR 24.5–61.6) ($p < 0.001$). 2D ED in the Angio-CT group (median 5.1 mSv, IQR 2.5–8.4) was 4 times lower compared to that in the CBCT group (median 20 mSv, IQR 10.1–35.8) ($p < 0.001$), whereas fluoroscopy times did not differ between both groups (median 18 min in the CBCT group vs. 17 min in the Angio-CT group, p = 0.518). Fewer DSA runs were performed in the Angio-CT group compared to the CBCT group (n = 1.0 vs. n = 3.0, $p < 0.001$). 3D ED in the Angio-CT group was almost 2.4 times lower than that in the ED in the CBCT group (7.4 vs. 17.9 mSv, $p < 0.001$), while in the Angio-CT group more 3D acquisitions were obtained (n = 2 vs. n = 1, $p < 0.001$). As regards CT acquisitions, CTDI was lower in the Angio-CT group (n = 53/57, median 10.2 mGy, IQR 7.1–15.8) compared to the CBCT group (using GE Optima 660, n = 9/57, median 16.9 mGy, IQR 15.6–17.5) (p = 0.003).

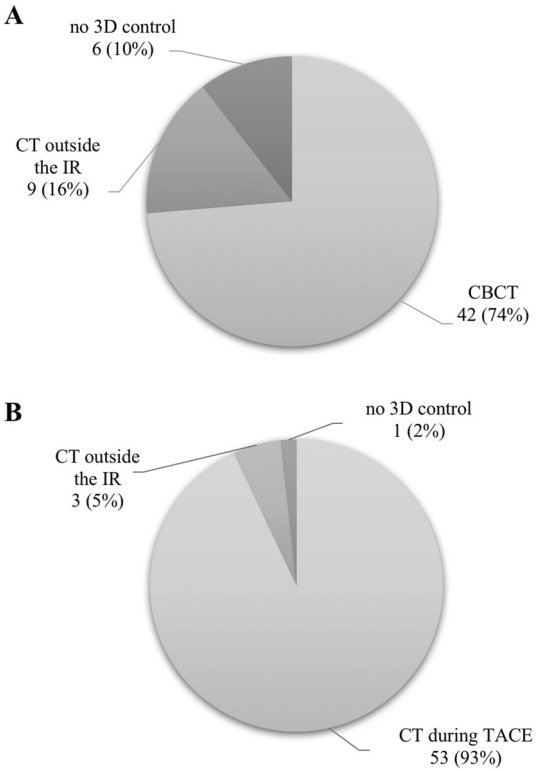

Fig. 3 3D control examination modalities repartition **A** in the CBCT group; **B** in the Angio-CT group

Tumor Targeting and Response

There was no significant difference in terms of classes of tumor targeting between both groups ($p = 0.509$, Table 3), either in the superselective TACE subpopulation ($p = 0.284$).

Tumor response was assessed for 108 TACE procedures (94.7%) with a mean time of 58 days between TACE and follow-up imaging examination which was MRI for 89 procedures (82.4%) and CT for 19 (17.6%), without significant difference between groups ($p = 0.503$). No significant difference was found between both groups either in terms of classes of tumor response ($p = 0.070$), or in terms of objective tumor response ($p = 0.084$) (Table 3), including after adjustment on anticancer agent used ($p = 0.090$).

Discussion

The most important finding of this study is that patient's radiation exposure during TACE strongly differs when comparing two high-end angiography suites with a 2.5 times lower total ED in the Angio-CT suite compared to the CBCT suite. Several hypotheses can be put forward to explain these differences in total ED. First, regarding 2D imaging ED, the lower number of DSA runs, owing to the use of 3D roadmapping based on CT acquisition, certainly reduced the radiation exposure in the Angio-CT group. In addition, the delivered radiation dose during fluoroscopy was reduced using this Angio-CT equipment, whereas fluoroscopy time was equivalent between both modalities. This may be explained mainly by the improved technology of the flat panel, but also by the availability and the systematic use of dose optimization tools provided by the Angio-CT suite such as the "live zoom" and the "spot

Table 2 Comparison of dose-related parameters per procedure between the two imaging modalities groups

	CBCT group ($n = 57$)	Angio-CT group ($n = 57$)	p value
ED (mSv)			
Total	39.2 (24.5–61.6)	15.4 (6.8–20.8)	< .001
2D	20 (10.1–35.8)	5.1 (2.5–8.4)	< .001
3D[a]	17.9 (15.5–20.9)	7.4 (3.8–14.6)	< .001
Fluoroscopy time (min)	18 (14–24)	17 (14–23)	0.518
Air kerma (mGy)	681 (481–1172)	249 (111–387)	< .001
DAP (mGy. cm^{-2})			
Fluoroscopy	50185 (29010–103267)	21467 (9758–32339)	< .001
DSA	58593 (28487–116329)	7691 (0–17766)	< .001
CBCT	59397 (46290–66401)[b]	–	
Number of DSA runs, excluding CBCT	3 (2–5)	1 (0–2)	< .001
Number of 3D exams, of all types	1 (1–1)	2 (1–3)	< .001

Data are median (interquartile range) values because of non-normally distributed variables

ED effective dose, *DAP* dose area product, *DSA* digital subtraction angiography, *CBCT* cone-beam computed tomography

[a]3D ED includes the exposure of both CBCT and CT acquisitions

[b]$n = 42/57$

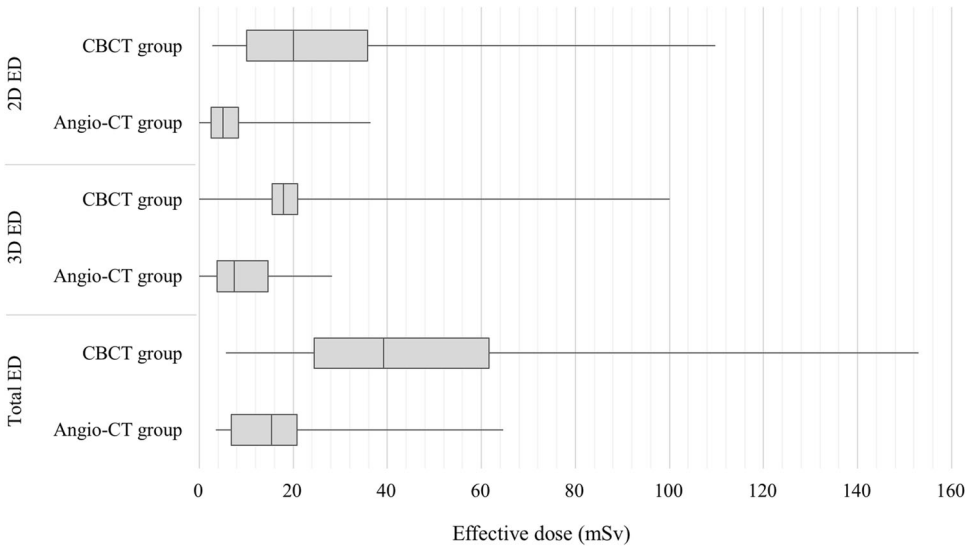

Fig. 4 Comparison of effective doses (ED) per procedure between the two imaging modalities groups

Table 3 Comparison of tumor targeting accuracy and oncological response between the two imaging modalities groups

	Total (n = 114)	CBCT group (n = 57)	Angio-CT group (n = 57)	p value
Treatment targeting	107 (93.9%)	51 (89.5%)	56 (98.2%)	0.509
Fully targeted	62 (57.9%)	28 (54.9%)	34 (60.7%)	
Partially targeted	44 (41.1%)	22 (43.1%)	22 (39.3%)	
Untargeted	1 (0.9%)	1 (2%)	0	
Tumor response	108 (94.7%)	53 (93%)	55 (96.5%)	0.070
Response	56 (51.8%)	23 (43.4%)	33 (60.0%)	
Stability	34 (31.5%)	17 (32.1%)	17 (30.9%)	
Progression	18 (16.7%)	13 (24.5%)	5 (9.1%)	
Objective tumor response	108 (94.7%)	53 (93%)	55 (96.5%)	0.084
Yes	56 (51.8%)	23 (43.4%)	33 (60.0%)	
No	52 (48.2%)	30 (56.6%)	22 (40.0%)	

Data are expressed as numbers (percentages)

CBCT cone-beam computed tomography

fluoroscopy" features. Regarding the 3D imaging ED, it was reduced by a factor 2 in favor of the Angio-CT, whereas there were twice the number of 3D acquisitions per procedure compared with CBCT. This might be explained by factors such as CT multidetector technology and last-generation iterative reconstruction algorithms. Importantly, its 320 detector rows allow a wide volume acquisition with a full liver coverage (16 cm) in a single rotation, thereby reducing the dose as compared to helical acquisition [26], resulting in lower CTDI (10.2 vs. 16.9 mGy, p = 0.003).

CBCT has proven to be superior in detecting tumors and feeding vessels in comparison with DSA alone [27, 28], providing additional information which impacts procedure strategy in 20% of cases [9]. CBCT also has limitations, besides a small FOV and poor signal-to-noise ratio in comparison with CT [8, 29, 30]; the technique is highly susceptible to artifacts due to patient position and respiratory motion [8, 29]. Because of these limitations, CBCT does not reach CT performances in tumor detection [31]. Lin et al. [32] have recently demonstrated that Angio-CT outperforms CBCT in TACE planning in terms of qualitative imaging quality.

Radiation exposure RL are intended to promote improvements in patient radiation safety by allowing comparison of radiation doses delivered during a specific type of IR procedure, across different institutions. For both IR suites, the results are in line with the radiation exposure

Table 4 Comparison between our study's results and the literature's published dose reference levels (RL) in TACE procedures

	N	Total ED (mSv)[a]	Air kerma (mGy)	Fluoroscopy time (min)
This study				
Angio-CT suite	57	15.4 (6.8–20.8)	249 (111–387)	17 (14–23)
CBCT suite	57	39.2 (24.5–61.6)	681 (481–1172)	18 (14–24)
Vano et al. [33][b]	149	24	–	30
Etard et al. [18][b]	397	40	990	28
Vano et al. [34][b]	151	46.2	–	24.3
Swiss FOPH [35]	–	48	–	20
Ruiz-Cruces et al. [36][b]	269	48.5	–	26.3
Miller et al. [37][c]	125	64	1900	25

N number of procedures, *ED* effective dose, *FOPH* Federal Office of Public Health

[a]Total ED was obtained converting DAP using 0.16 mSv Gy^{-1} cm^{-2} conversion factor [20]

[b]RL were defined as the third quartiles of the distribution

[c]RL were defined the as the rounded values approximately midway between the third quartile and the upper bound of the third quartile

RL suggested by the literature in TACE procedures [18, 33–37]. Regardless of the modality used, total ED, air kerma and fluoroscopy times were lower than the published RL, except regarding CBCT suite for which the total ED (39.2 mSv) is higher than RL suggested in the European survey of Vano et al. (DAP 150 Gy cm^{-2} = ED 24 mSv) [33]. However, in their study, differences up to sixfold between centers for both DAP and fluoroscopy third quartiles were reported. Also mentioned by the authors themselves, the RL proposed in their study should be considered very cautiously and only as a first approximation. Furthermore, considering the fact that the total ED as defined in our study also includes ED of 3D control examination when performed (regardless of its modality), our practices, especially using Angio-CT, result in much lower radiation exposure compared with published RL (Table 4).

There are several limitations to this study. First, because the CBCT suite was replaced by the Angio-CT suite, a prospective comparison between both imaging modalities could not be performed. Thus, the retrospective design of the study should be taken into account regarding the generalizability of the results. Second, although ED is the appropriate tool to compare radiation exposure from imaging modalities that deliver different spatial distributions of doses within a patient's body (i.e. CT vs. CBCT in this study), conversion factors used to calculate ED might influence results accuracy. This study considered TACE-specific conversion factors to minimize this influence. Third, it would have been interesting to compare the image quality between groups. However, objective comparison measuring signal/contrast to noise ratio was not possible since images were generated from different patients with different imaging modalities. Subjective comparison using published image quality scales could not be possible either. Indeed, in our work DSA acquisitions were not routinely performed with Angio-CT since they have become useless, owing to CT-arteriography and 3D road mapping. Only 2D fluoroscopy was performed in both groups and could, theoretically, be compared. However, 2D fluoroscopy runs were rarely captured in our routine practice, thereby preventing any retrospective evaluation. Fourth, newer Angio systems with CBCT exist nowadays and are provided with technological improvements that our system did not support (e.g. shorter rotation time and image fusion technique). Since the use of an older system could have influenced radiation exposure during TACE, it is important to mention it as a study limitation. Fifth, ten senior radiologists performed the TACE procedures in our study and this can be seen as a limitation since TACE technique may slightly differ from an operator to another. Nevertheless, this also can be seen as strength since it reflects real life of an IR department and reduces the risk of operator technique being a confounding factor regarding the differences in terms of patient's radiation exposure between both study groups. Finally, our experience with both systems was unbalanced (6 years with CBCT vs. 3 weeks with Angio-CT before including patients for this study), underlying even more the benefit of Angio-CT in terms of radiation exposure.

To conclude, Angio-CT provides a significant decrease in patient radiation exposure during TACE procedures compared to the conventional angiography suite using an Angio system with CBCT.

Compliance with Ethical Standards

Conflict of interest Boris Guiu has received honorarium from Canon Medical System for symposium lectures during ECIO, CIRSE, ECR meetings. There is no other relationship to disclose.

Ethical Approval For this type of study, formal consent is not required. Institutional Review Board approval was obtained.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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