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CLINICAL INVESTIGATION NON-VASCULAR INTERVENTIONS

Cone-Beam CT-Assisted Ablation of Renal Tumors: Preliminary Results

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Abstract

Introduction Renal ablation is a recognized treatment modality for small renal masses. Cone-beam CT (CBCT) has been recently used in interventional oncology as a promising new guidance device, but this technology still needs to be validated for renal ablations. We aimed to assess the technical success of CBCT applications in renal ablative treatments.

Materials and Methods Between March 2016 and June 2018, 14 patients (mean age 69, range 54–83, 7F, 7M) underwent 21 renal ablations for histologically proven renal cell carcinoma (RCC). All treatments were performed with ultrasound (US) and CBCT guidance under general anesthesia in a dedicated angiography room setting. CBCT was mainly used to assess needle placement and to exclude complications at the end of the procedure. In two small lesions (< 1 cm), pre-acquired CBCT was co-registered with real-time US to obtain a US-CBCT fusion image guidance for tumor ablation.

Results Whether used alone or in combination with other imaging modalities, CBCT was proven to be technically successful in all 21 procedures to guide or assist tumor ablation. A primary technical efficacy of thermal ablation was achieved in 19/21 ablations (90.1%) at 1 month. Mean procedure duration was 100.2 min (range 160−64). Mean length of hospital stay was 2 days (range 1–10 days). All patients are still under active surveillance for a mean follow-up of 14.5 months (range 4–26 months).

Conclusions CBCT for renal ablation guidance is a viable tool. Larger series are needed to compare it to MDCT.

Keywords Cone-beam computed tomography · CBCT · Renal ablation · Thermal ablation · Tumour · Kidney

Abbreviations

IO	Interventional oncology
CBCT	Cone-beam computed tomography
MDCT	Multidetector computed tomography
CT	Computed tomography
US	Ultrasound
FOV	Field of view
RCC	Renal cell carcinoma

Introduction

Image-guided ablations are gaining increasing attention in the current clinical practice for the treatment of renal tumors [1–4]. These techniques provide a relevant

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advantage over standard surgical resection, including reduced invasiveness, low morbidity, and preservation of renal function [5–8]. Dedicated guidelines for renal ablation have been recently published, highlighting the crucial role of multidetector computed tomography (MDCT) guidance [9]. Because of its wide availability in interventional rooms and its real-time capability, ultrasound (US) is the most used technique for renal ablation. However, the role of MDCT is regarded as crucial because of its ability to provide a precise evaluation of the anatomical relationship between the target and the surrounding organs (especially the bowel loops), resulting in a precise confirmation of correct ablative device positioning in cases of poor US visibility, and an immediate evaluation of the effectiveness of the treatment. The ideal setting for renal ablation is represented by an operating room containing dedicated interventional MDCT and US, previously named *hybrid CT/angiography suite* [10]. This notwithstanding, some institutions might not have a dedicated interventional MDCT room or its use for interventional procedures may be hampered by the heavy workload high-volume hospitals daily face.

Cone-beam computed tomography (CBCT) is an imaging modality integrated in modern angiography suites. It consists of a C-arm with a flat panel detector that rotates around the patients in a time-lapse fast enough to ensure raw data collection; this allows 3D images on a selected volume to be produced usually with a relatively small field of view (FOV). CBCT has already been referred to several applications in interventional oncology (IO) [11]; still, to the best of our knowledge, no experience has yet been reported in renal ablations. The purpose of our study was to assess the technical success of renal ablation performed in the angio suite with US guidance and CBCT assistance.

Materials and Methods

Patients

Institutional review board approval was obtained. Patients provided written informed consent for the use of clinical data for research purposes. From March 2016 to June 2018, 14 patients (7 males, 7 females, age range 54–83, mean 69 years) underwent 21 percutaneous thermal ablations for histologically proven renal malignant renal tumors. The median size of the lesions was 20.6 mm (range 8–38 mm). Patients details, including the RENAL score [12], are listed in Table 1. Patients candidate for renal ablation were treated in a dedicated angio suite with a US machine, equipped with in-house fusion software, and CBCT angiography. Indication for ablative treatment was discussed in all cases in a multidisciplinary meeting involving urologists, nephrologists, surgeons, and the radiologist. Inclusion criteria consisted in biopsy-proven renal masses smaller than 4 cm (T1a) or a new growing lesion in patients previously treated surgically for renal cancer. Exclusion criteria included metastatic disease and coagulopathy.

Procedure

All procedures were performed under general anesthesia in the angiography room with the patient lying in the most favorable position for direct needle approach using both US and CBCT [13]. All patients were placed in the proper decubitus with the assistance of a dedicated nurse and in coordination with the anesthesiologist. CBCT rotation was verified each time before scanning to be certain not to displace the plastic junction to the endotracheal tube. All

Table 1 Demographics and clinical characteristics of patients undergoing CBCT-assisted renal ablation

#	Sex	Age	Diagnosis	No. sessions	Single kidney	Lesion diameter (mm)	RENAL score
1	m	71	Clear cell RCC	5	y	8, 12, 18, 9, 11	a6, p10, p10, p6, a7
2	m	70	Clear cell, papillary RCC	2	n	27, 22	a8, x8
3	m	81	Clear cell RCC	2	n	32	p4, p4
4	f	68	Clear cell RCC	2	n	38	p8, p8
5	f	66	Chromophobe RCC	1	n	21	p6
6	m	83	Clear cell RCC	1	n	19	p5
7	f	62	Clear cell RCC	1	n	28	p5
8	f	54	Clear cell RCC	1	y	12	p7
9	f	77	Clear cell RCC	1	n	22	p4
10	m	59	Clear cell RCC	1	y	8	a6
11	f	81	Clear cell RCC	1	n	29	p9
12	m	56	Clear cell RCC	1	n	25	x8
13	m	69	Papillary RCC	1	n	23	p6
14	f	67	Clear cell RCC	1	y	28	x6

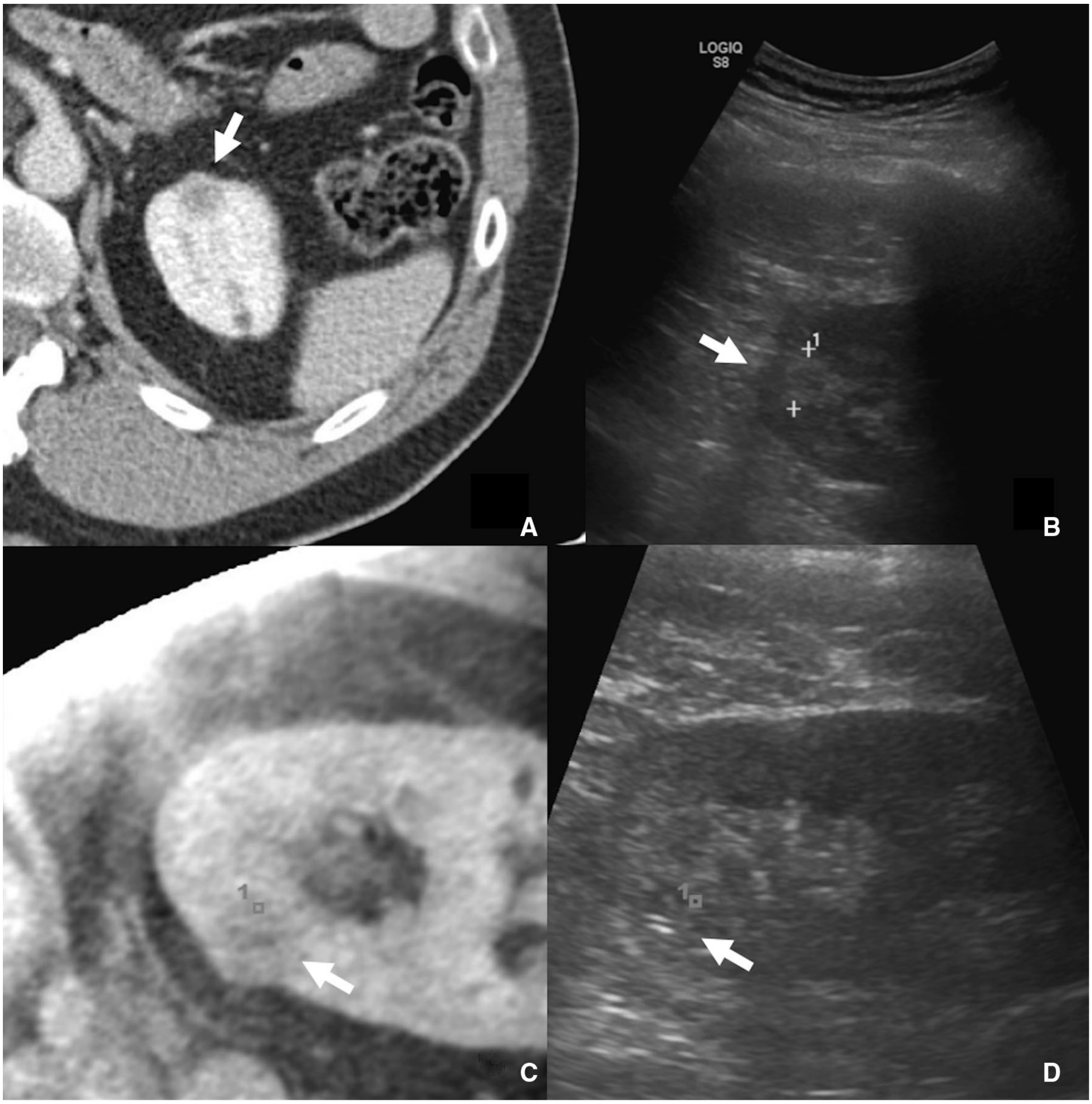

Fig. 1 **A** MDCT scan displaying an RCC relapse in the upper pole of the left kidney (arrow) after right nephrectomy; **B** US appearance of the lesion (arrow), **C**, **D** CBCT-US fusion imaging showing the exact location of the lesion (arrow) and allowing for a single-shot correct needle deployment

procedures were performed by the same interventional radiologist with more than 15 years of experience using a single RF needle with a maximum opening size of 4 cm. In cases where US allowed confident lesion detection [9], as per a normal CT-guided procedure, the needle was advanced under US guidance and then contrast-enhanced CBCT was used to visualize the needle, in order to avoid deviation from the intended path. Likewise, the hook position was confirmed to be in site with regard to the lesion margins. In cases with poor US visualization, a radiofrequency probe was advanced step by step toward the lesion during consecutive CBCT checks as per a normal CT-guided biopsy or drainage placement. We also used US-CBCT fusion imaging as image guidance for needle positioning (Fig. 1). A contrast-enhanced CBCT scan acquired at the very beginning of the procedure was fused with real-time US to allow more efficient needle deployment, also resulting in fewer CBCT scans required to track needle positioning. For CBCT-guided and US-CBCT-guided procedures, the first contrast-enhanced scan was performed before needle placement, while a second scan, usually unenhanced CBCT, was performed after needle positioning in all cases. Safety measures like hydrodissection and retrograde pyelo-perfusion were performed for any lesion close to surrounding organs or to the collecting system, respectively.

A flat panel angiography system (Artis Zee, Siemens Healthcare AG, Forchheim, Germany) was used to obtain contrast-enhanced (100 ml, Ultravist 370 mg/ml and flow rate of 3.5 ml/s) CBCT images with a 7-s C-arm rotation time in both the arterial and portal phases. A pre-arranged delay of 35 s from injection was established for the arterial phase and a delay of 70 s for the portal phase, respectively. A breath-hold apnea at the same lung expansion was performed by the anesthesiologist during both acquisitions.

The CBCT acquisition parameters were: rotation angle 200° and angulation step 0.5°. A 512 × 512 pixel matrix with about 400 images per volume was used. The isotropic voxels had an approximate size of 0.5 mm^3. The syngo X-workplace for Dyna CT was used (Siemens Healthcare, Malvern PA, USA) to process images after volume acquisition. The mean waiting time from acquisition to image visualization was about 10 s.

Fusion imaging was performed by co-registration of the 3D contrast-enhanced CBCT dataset with real-time US images. US imaging and needle guidance were performed using a dedicated US scanner configured with Volume Navigation (LOGIQ S8 XDclear 2.0, GE Healthcare, Ill-USA) and a C1-6 VN US transducer with an electromagnetic sensor inside. Using general anesthesia, fused US was performed exactly in the same decubitus and apnea as per CBCT, looking for precise image matching. US-CBCT fusion technique has already been described in preliminary studies [14].

All radiofrequency ablations were performed with an RF 3000 (Boston Scientific, Natick, Massachusetts, USA) system and a retrievable hook-umbrella needle (size 2–4 cm); a maximum power of 120 W was delivered until roll-off was reached, twice per each needle deployment.At the end of the procedure, a contrast-enhanced CBCT scan was performed for early treatment evaluation and to identify immediate complications.

All patients underwent overnight observation and were discharged the following day if clinically stable. Prior to discharge, a complete blood count and contrast-enhanced MDCT were performed to rule out any occult complication.

Outcome Measurements and Variables

The primary outcome measurement of this study was to assess the technical success of renal RFA with CBCT assistance. Secondary outcome measurements were technical success, primary technical efficacy, procedure length, and complications.

- The technical success of CBCT-assisted renal ablation was defined as the possibility of performing CBCT to assess needle position and tumor coverage at immediate postprocedural CBCT [15].
- The primary technical efficacy was defined according to the standard definition [15] and evaluated at 1-month MDCT. The secondary technical efficacy defined successful repeat ablation following identification of local tumor progression [15].
- Procedural time was considered as the time from anesthesia induction to the patient awakening.
- Complications were defined accordingly to CIRSE criteria [16].
- Follow-up was considered from the first treatment (March 2016) until the time of writing.

Results

Renal RF ablation was technically successful in 21 cases at the final contrast-enhanced CBCT control. An intraprocedural CBCT scan assessed the correct probe deployment after US-guided procedure in 15/21 cases (71.4%), while fusion CBCT-US imaging was used in 2/21 cases (9.5%). In four cases (19%), only CBCT was used throughout the procedure. Early post-procedural contrast-enhanced CBCT assessment allowed for the immediate identification of viable tumor areas in 4/21 procedures (19%) and for successful re-treatment after proper needle repositioning.

Primary technical efficacy at 1 month was reached in 19 out of 21 cases (90.1%) in a single session. In two cases, the patient underwent a second image-guided thermal ablation successfully (100% secondary technical efficacy). Ten patients received a single treatment, and three patients received treatments in two sessions. Because of metachronous multifocal relapse after radical nephrectomy for renal cell carcinoma, patient #1 received treatments over five sessions until lung progression required systemic treatment with sunitinib (Table 1). The mean procedure duration was 100.2 min (range 64–160 min), with a mean number of 7.3 scans per procedure (range 14–4). Safety measures like hydrodissection and retrograde pyelo-perfusion were performed in 1 and 3 procedures, respectively.

When CBCT was the only imaging modality used, the mean number of scans per procedures was considerably higher than US-guided procedures (mean number of 13 scans versus 7.3 scans). In all cases, beam hardening artifacts did not hamper the imaging quality to the point of undermining the technical success of the procedure. No procedure-related complication was reported at the immediate post-procedural control nor after patients' discharge. Mean length of hospital stay was 2 days (range 1–5).

All cases were recurrence-free at MDCT control performed at 4 months (mean follow-up of 14.5 months, range 4–26 months).

Discussion

This study represents a preliminary experience on the role of CBCT for image-guided renal ablation. Since March 2016, all cases of renal ablation were performed in our institution using CBCT as image guidance, reporting excellent technical success, primary technical efficacy, and safety profile in a small group of 21 tumors.

Extravascular applications of CBCT are still limited, especially for non-hepatic interventions. Even though a small series of CBCT-guided liver ablations have been published [17, 18], there is no report about CBCT-guided renal interventions, with the exception of a few papers which investigated the advantages and limits of CBCT in percutaneous renal biopsies [11, 19–21].

In our small cohort of patients, the technical success of CBCT-guided ablations was in line with some of the latest major studies published on this topic [22, 23]. The only paper reporting CBCT-guided renal ablation is a recent paper from Abi-Jaoudeh et al., which used CBCT for lesion ablation in different primary tumors including 7 renal cell carcinomas [24]. However, several differences must be noted: no data about renal tumor dimensions were therein available and US was never used as an image guidance tool, a fact that could have significantly increased the number of CBCT scans required for correct needle deployment. By contrast, our retrospective analysis has been completely focused on renal tumors. Whenever accessible, we made use of US alone or US combined with pre-acquired contrast-enhanced CBCT in order to decrease radiation exposure and to take advantage of real-time image guidance. As already described in liver ablation [2], we believe fusion imaging to be a feasible and practical approach, especially in time-consuming procedures such as renal ablations, which last about 100 min from induction of general anesthesia to patient wake up. Despite the logistical effort and the long times required, general anesthesia was found to be a very useful tool to accurately and safely ablate renal lesions, as also recommended by recent European guidelines [9]. The success of any ablative treatment strongly depends on accurate probe placement. General anesthesia may help because of controlled respirations, elimination of patient movement, and minimization of motion artifacts [25, 26]. Moreover, the possibility of switching off the ventilator during the lesion targeting allows the radiologists to acquire better images in the targeting phase and to easily place the RF probe within the lesion [27].

As previously stated, comparing conventional CT with CBCT was not our aim; we agree that image quality may still be higher with conventional CT than with CBCT, even if this gap is swiftly shrinking as a result of rapid developments in CBCT technology [28].

Regarding FOV size, CBCT provides limited FOV compared to CT, and this may generate difficulties in understanding complex anatomy or in approaching patients with large body size and multiple tumors [10]. Beyond technical differences among CT and CBCT, operating in an angio suite has some relevant advantages in terms of safety, patient management, and optimization of the workflow. Being the CT interventional room and the angio suite both non-operating room anesthesia (NORA) environments, the angio suite is a setting where anesthesiologists and operators can easily perform general anesthesia and benefit from dedicated monitoring tools, drugs, and interventional devices stored therein [29]. This setting also helps to timely deal with intraprocedural complications (i.e., intraprocedural bleeding). Moreover, when pre-procedural or post-procedural embolization is required, being able to deliver the treatment in one session optimizes patient care.

Whenever available, conventional CT remains of paramount importance for percutaneous renal ablation; however, the ideal scenario of having a conventional CT or a hybrid suite dedicated to interventional oncology (IO) is affordable only in selected referral cancer centers [10, 30]. In contrast, CBCT has been recognized as an easier compromise for combining angiography and CT and it is becoming increasingly used in the IO setting [17]. Moreover, combining US with CBCT seems an effective method to improve lesion targeting and to reduce the number of CBCT scans, possibly bypassing the necessity to resort to state-of-the-art MDCT.

Our study has several limitations, the most relevant being the small number of patients recruited, the retrospective study design, and the lack of a conventional CT control group to compare technical success and procedural details. In addition, we did not aim to confirm previous papers which described higher doses delivered by MDCT compared to CBCT [31–33]. Additionally, patient follow-up is relatively short, considering that most local recurrences occur between 18 and 24 months. However, unlike large clinical studies that evaluated the efficacy of percutaneous thermal ablation in the kidney [34–38], our aim was to validate CBCT as image guidance and present its different uses for renal ablations (Fig. 2).

Our preliminary experience confirms CBCT-assisted renal RF ablation to be technically feasible, effective, and safe. Despite the small number of patients treated so far, we believe these initial data to be of interest for those operators who do not have access to a CT interventional room, and we endorse the role of CBCT in percutaneous renal ablations.

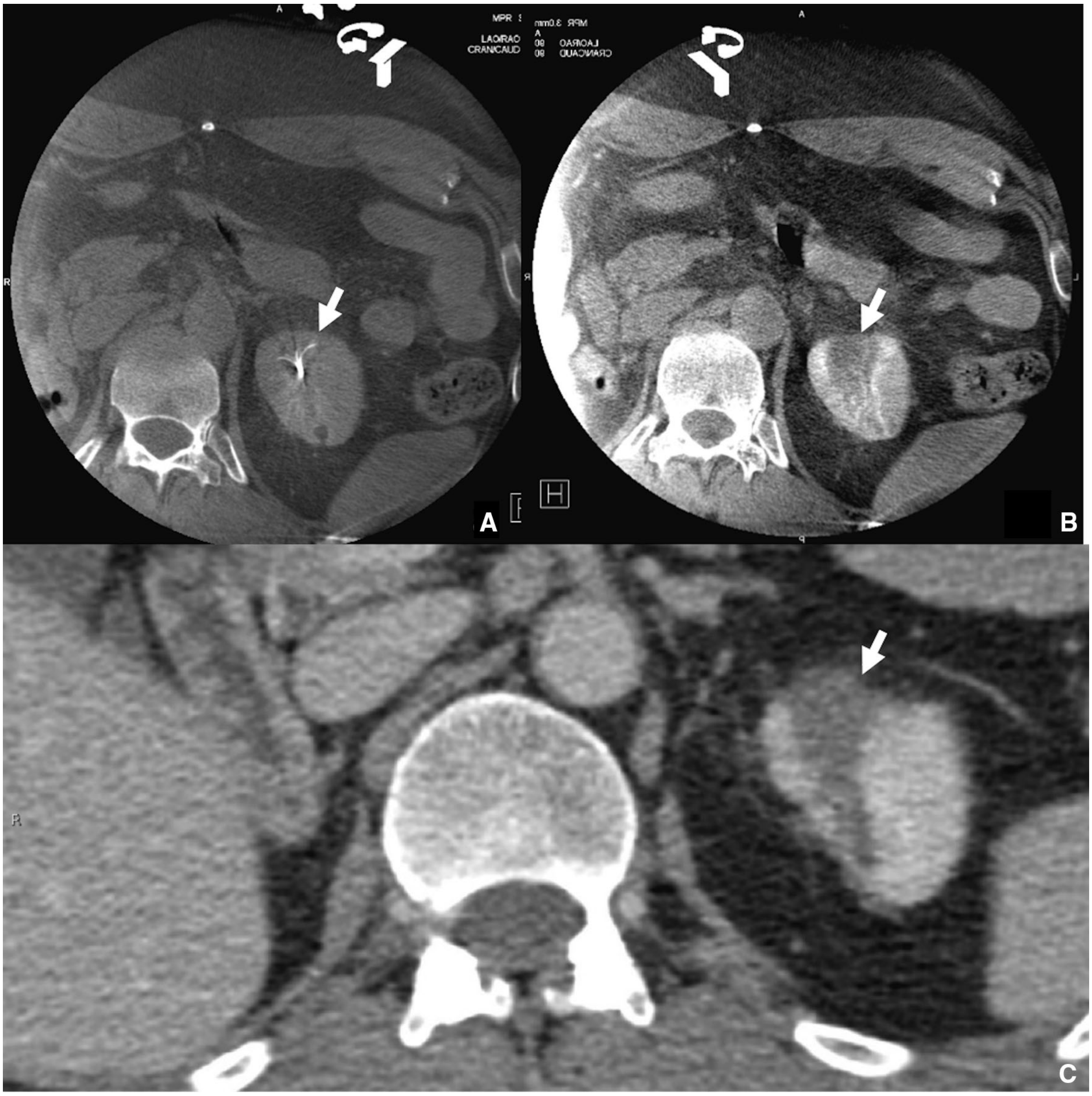

Fig. 2 **A** CBCT control to assess correct needle and hooks placement (arrow), **B** contrast-enhanced CBCT control directly after the treatment suggesting complete ablation (arrow), **C** contrast-enhanced MDCT 6-month follow-up confirming the success of the procedure (arrow)

In conclusion, CBCT is a viable tool that is of assistance in percutaneous renal ablation and in the immediate evaluation of the technical success of the procedure similarly to MDCT. Larger series are needed to compare it to MDCT and to consolidate the role of CBCT as image guidance for renal ablations.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Standards Authors state that all procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or National Research Committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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

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