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RESEARCH ARTICLE

Utilization of flat-panel detector computed tomography for evaluation of COVID-19 pneumonia during neurointerventional procedures

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ABSTRACT

Utilization of flat-panel detector computed tomography for evaluation of COVID-19 pneumonia during neurointerventional procedures

Introduction: This study aimed to evaluate the imaging findings of the chest flat panel detector computed tomography (FDCT) among coronavirus disease-2019 (COVID-19) positive patients during urgent/emergent interventional neuroradiologic procedures.

Materials and Methods: Chest FDCT examinations were performed using a C-arm mounted FDCT within the interventional radiology (IR) suite if the reverse transcription polymerase chain reaction (RT-PCR) results were pending in patients with clinical findings suggestive of COVID-19. In those who already had positive RT-PCR results, FDCT was performed for acute evaluation only if an acute unexpected cardiopulmonary event occurred during the procedure. FDCT images were evaluated retrospectively by a thoracic radiologist based on Radiological Society of North America classification.

Results: Eleven patients (four males, four females, one boy and two girls) with positive RT-PCR test results were included. Six presented for acute ischemic stroke treatment, three children had retinoblastomas, and two patients had hemorrhagic strokes. One (9.1%) patient had typical CT findings of COVID-19, whereas 4 (36.4%) patients had indeterminate findings. Six (54.5%) patients had no findings suggestive of COVID-19. The most common parenchymal finding was atelectasis (eight patients), followed by consolidation (five patients), pleural effusion (two patient) and pulmonary mass lesion (one patient).

Conclusion: This study is the first in the literature utilizing C-arm FDCT for dedicated thoracic imaging at the IR suite. Ability to perform on-site chest CT without a need to transfer the patient to a regular CT scan may be helpful in

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both the management of acute pulmonary complications that occur during interventional procedures and pre-interventional assessment for pulmonary conditions like COVID-19 in the IR suite in emergent interventions.

Key words: COVID-19 pneumonia; flat-panel detector CT; chest CT; neurointerventional radiology; acute stroke

ÖZ

Nöro girişimsel radyoloji işlemleri sırasında COVID-19 pozitif hastalarda elde edilen toraks flat-panel dedektör bilgisayarlı tomografi görüntüleme bulgularının değerlendirilmesi

Giriş: Bu çalışmanın amacı, acil girişimsel nöroradyolojik işlemler sırasında koronavirüs hastalığı-2019 (COVID-19) pozitif hastalarda toraks flat-panel dedektör bilgisayarlı tomografi (FDBT) görüntüleme bulgularını değerlendirmektir.

Materyal ve Metod: COVID-19 düşündüren klinik bulguları olan hastalarda özellikle revers-transkriptaz polimeraz zincir reaksiyonu (RT-PCR) sonuçları mevcut değilse, girişimsel radyoloji odasında C-kollu bir FDBT kullanılarak toraks FDBT incelemeleri yapıldı. RT-PCR sonuçları pozitif olan hastalarda ise akut değerlendirme için FDBT yalnızca işlem sırasında akut beklenmedik bir kardiyopulmoner olay meydana gelmesi halinde gerçekleştirilmiştir. Flat-panel dedektör bilgisayarlı tomografi görüntüleri bir torasik radyolog tarafından Radiological Society of North America sınıflandırmasına göre retrospektif olarak değerlendirildi.

Bulgular: RT-PCR test sonuçları pozitif olan 11 hasta (dört erkek, dört kadın, bir erkek çocuk ve iki kız çocuk) çalışmaya dahil edildi. Altı hasta akut iskemik inme endovasküler tedavisi için başvurdu, üç çocukta retinoblastom ve iki hastada hemorajik inme vardı. Bir (%9.1) hastada COVID-19'un tipik BT bulguları varken, 4 (%36.4) hastada belirsiz bulgular vardı. Altı (%54.5) hastada COVID-19'u düşündüren hiçbir bulgu yoktu. En sık görülen parankimal bulgu atelektazi (sekiz hasta) olup, bunu konsolidasyon (beş hasta), plevral efüzyon (iki hasta) ve pulmoner kitle lezyonu (bir hasta) takip etmektedir.

Sonuç: Bu çalışma, literatürde girişimsel radyoloji odasında özel torasik görüntüleme için C-kollu FDBT kullanan ilk çalışmadır. Hastayı standart bir BT cihazına nakletmeye gerek kalmadan FDBT ile toraks BT tetkikinin elde edilebilmesi, hem girişimsel prosedürler sırasında ortaya çıkan akut pulmoner komplikasyonların yönetiminde hem de acil müdahalelerde girişimsel işlem odasında COVID-19 gibi pulmoner durumlar için girişim öncesi değerlendirmede yardımcı olabilir.

Anahtar kelimeler: COVID-19 pnömonisi; flat-panel dedektör BT; toraks BT; girişimsel nöroradyoloji; akut inme

INTRODUCTION

The novel coronavirus (SARS-CoV-2019) was first reported in December 2019 in China, and it soon became a global health problem as a global pandemic was declared by World Health Organization in March 2020. The clinical condition caused by the virus was named as COVID-19, and the clinical presentation was dominated by acute pneumonia that pursued a more morbid course among the elder population or patients with hypertension, obesity or any clinical condition causing immunosuppression (1-4). To date, the gold standard for the diagnosis of this disease remains as reverse transcription - polymerase chain reaction (RT-PCR) test; however, reported false positive or negative rates associated with RT-PCR are the main drawbacks of this method (5). Hence, imaging findings detected on either chest X-rays or chest computed tomography (CT) examinations are still an integral part of clinical evaluation and diagnosis as well as follow-up of the patients with equivocal clinical findings and negative RT-PCR results (6). Additionally, thoracic imaging has clinical significance as the severity of the disease may correlate with the severity and multiplicity of the thoracic lesions. In this study, it was aimed to report the flat panel chest CT findings of COVID-19 in patients who underwent interventional neuroradiologic proce-

dures. Since the flat panel CT, which is a C-arm mounted flat panel detector computed tomography (FDCT), is routinely available and utilized in modern interventional radiology (IR) procedure rooms, logistically, it is effortless to obtain thoracic imaging if clinical indication exists.

MATERIALS and METHODS

Patient Population and Imaging Protocol

This retrospective study was approved by the local institutional review board. We retrospectively evaluated all patients treated between March 2020-May 2024 in our neuroangiography suite in whom a chest FDCT was obtained to evaluate a possible COVID-19 positive status. The patients included those with acute ischemic stroke (AIS) due to large vessel occlusion, acutely ruptured aneurysm referred for emergent endovascular treatment, children with retinoblastoma who were referred to our department for intra-arterial chemotherapy (IAC) and cerebral angiography. If the RT-PCR result for COVID-19 was positive prior to or after the endovascular procedure, then the patient was diagnosed to be COVID-19 positive.

Since all endovascular mechanical thrombectomy procedures were performed on an emergency basis,

none of the AIS patients had a known RT-PCR result antecedent to the procedure. In our hospital, during the COVID era, oral and nasopharyngeal swabs for RT-PCR were obtained from all ischemic or hemorrhagic stroke patients admitted to the Emergency Department; however, it usually takes several hours to get the laboratory results. If a patient with ischemic or hemorrhagic stroke needs emergent treatment, delaying the endovascular procedure to learn about the laboratory results is not acceptable. For these patients, we routinely obtain CT angiography (CTA) of the head and neck. Although bilateral lung apices were included in routine head and neck CTA and additionally non-contrast chest CT was obtained in emergency department for some of these patients, the examinations were generally inconclusive due to uncooperative, apprehensive and disoriented status of the patients as well as resultant widespread motion and respiratory artifacts. Hence, we performed chest FDCT immediately after anesthesia and just before the endovascular procedures in all stroke patients eligible for endovascular treatment in the angiography suite. The adult patient who had a known PCR positivity for COVID-19 in this series was prepared for a cerebral angiogram, but the procedure was aborted based on chest FDCT findings.

In addition to the adult patients, we obtained FDCT in several of the children who presented for IAC for retinoblastoma. Since these patients were treated electively, they generally had negative RT-PCR results. However, several children had to be treated during RT-PCR positivity to comply with the monthly chemotherapy schedule as judged to be necessary by the joint decision of the attending ocular oncologist and pediatric oncologist. In these RT-PCR positive children, due to the difficulties of obtaining a reliable swab and due to the disparity of the clinical findings (which are milder than adults) and imaging findings related to the lung involvement, we routinely obtained a chest FDCT (7). The purpose was to keep the patient intubated if there was significant pulmonary involvement and proceed with extubation in the pediatric intensive care unit (ICU) reserved for COVID positive patients. Otherwise, the patient was to be awakened and sent to the pediatric COVID ward.

Demographic data and relevant clinical data were obtained from the hospital information system. The follow-up clinical status of the patients was evaluated per the modified Rankin scale (mRs). Information relevant to the general medical history, clinical

follow-up, systemic findings of the patients during their hospital stay and at the time of the discharge were extracted. Patient demographics and descriptive statistics were given as percentages and mean (minimum-maximum) values.

FDCT Imaging Protocol and Radiological Interpretation

All endovascular procedures were performed with a biplane angiography unit (Siemens Artis Zee). Other than the two patients who ended up with only a diagnostic cerebral angiogram, all procedures were performed under general anesthesia. In these patients, chest FDCT was obtained within the angiography suite during breath-hold with deep inspiration. Standard imaging parameters for chest FDCT were as follows: Voltage= 79 kV; tube current= 150-320 mA; rotation angle= 200; rotation time= 20 seconds.

During endovascular procedures, the images were transferred to the local post-processing workstation to be evaluated by the radiologists performing the procedures. However, for the purpose of the current study, a thoracic radiologist with seven years of experience in chest imaging, blinded to the RT-PCR results and clinical status of the patients, interpreted the chest FDCT images electively. First, the examinations were classified as diagnostic or non-diagnostic based on the quality of images. If the examination was classified as a diagnostic one, then the pulmonary findings of the patients were evaluated with regard to the diagnosis of a possible or definite COVID-19. For evaluation of CT findings of COVID-19, the Radiological Society of North America (RSNA) classification scheme was used and findings were classified as typical, indeterminate, atypical and negative for COVID-19 (8). Other incidental or accompanying pathological findings both in the lung parenchyma and neighboring soft tissue and bony structures such as mass lesions and pleural effusion were noted by the thoracic radiologist.

RESULTS

A total of 11 patients (4 males, 4 females, 1 boy and 2 girls) with positive RT-PCR test results were included in the study. Mean RT-PCR positivity was 0.7 days. Of these 11 patients, six were taken to the angiography suite with a presumptive diagnosis of AIS, three had retinoblastoma and two patients had a hemorrhagic stroke (one patient with an acutely

ruptured posterior communicating aneurysm and one patient with a recurrent right frontal lobar hematoma secondary to infective endocarditis). Mean age was 40.3 for all patients (minimum-maximum: 1-83), whereas 52.8 (minimum-maximum: 19-83) for AIS patients. Detailed demographical information and accompanying medical conditions and diagnoses for each patient are presented in Table 1.

All 5 mechanical thrombectomy procedures were angiographically successful (modified TIC1 2B/C-3). Three of these five patients expired within the first week after the procedure. First patient, a 19-year-old male with a remote history of cardiac valve replacement presented with acute right MCA occlusion. After successful recanalization, he was extubated uneventfully, and a postoperative day one control head CT was unremarkable. On the third day

after the procedure, when his NIHSS score was recorded as 0, he deteriorated suddenly, and his head CT revealed an acute basal ganglia hematoma which rapidly increased in size causing herniation and death. There was gram positive bacteria in his pathological examination of the thrombectomy material suggesting infective endocarditis as the source. The other two patients expired two and three days after the procedure due to complications of COVID-19 pneumonia and sepsis. The other two AIS patients had an mRs of one on clinical follow-up. As for FDCT imaging, only one of these AIS patients had COVID symptoms (fever) before the procedure, and this patient had indeterminate findings on chest FDCT. Otherwise, the chest FDCTs were unremarkable with regard to COVID-19 findings.

In the patient undergoing an angiogram, the patient was prepared and draped for angiography. Just after

Table 1. Demographic and clinical–radiological findings of the patients

Patient no.	Age/ Sex	Clinical Diagnosis	Accompanying Medical Conditions	COVID Symptomatology	RSNA Classification	Accompanying Pulmonary Findings	Follow-up mRs
1	19/M	AIS	Cardiac valve replacement	-	Negative	Atelectasis	6
2	45/F	AIS		-	Negative	Atelectasis	1
3	78/M	AIS		-	Negative	Atelectasis & mass lesion	6
4	83/M	AIS		Fever	Indeterminate	GGO & consolidation	0
5	68/F	AIS	Laryngeal cancer, diabetes mellitus	Fever	Negative	Atelectasis, pleural effusion	6
6	24/M	Multiple sclerosis		-	Typical	GGO & consolidation	0
7	50/M	Acute subarachnoid hemorrhage-ruptured aneurysm		-	Indeterminate	Atelectasis, consolidation	6
8	66/F	Hemorrhagic stroke-frontal lobar hematoma	Aortic & mitral valve replacement, diabetes mellitus, cardiac by-pass, atrial fibrillation	Fever & dyspnea	Indeterminate	Atelectasis, consolidation & pleural effusion	1
9	1/F	Retinoblastoma	None	-	Negative	Atelectasis, selective right bronchial intubation	0
10	4/M	Retinoblastoma	None	-	Negative	Atelectasis	0
11	5/F	Retinoblastoma	None	-	Indeterminate	GGO, consolidation	0

mRs: modified Rankin scale, GGO: Ground glass opacity, AIS: Acute ischemic stroke.

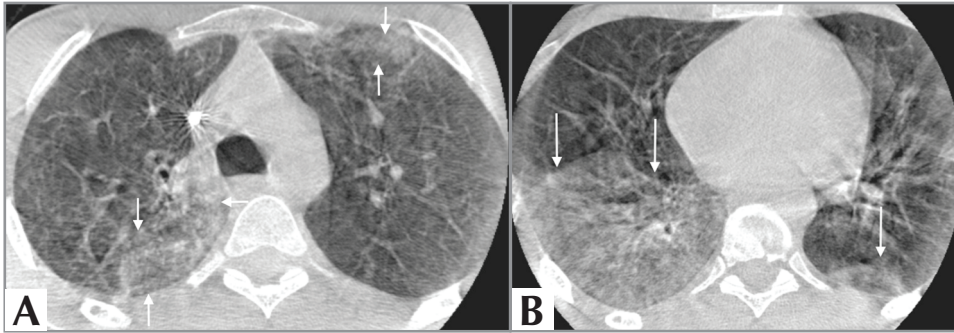


Figure 1. A, B. Axial chest flat-panel CT images show bilateral ground-glass opacities (white arrows) associated with COVID-19 pneumonia.

administration of local anesthesia at the femoral puncture site, the patient got agitated. The attending anesthesiologist requested a chest CT before administering deep sedation. As the patient was already on the angiography table, a chest FDCT was obtained instead. Based on the pulmonary findings disclosed on the chest FDCT, the anesthesiologist advised postponing the angiogram and the procedure was aborted. From the perspective of a COVID infection, the patient was asymptomatic; however, his chest FDCT was typical for COVID-19 (Figures 1 A, B). The patient was finally diagnosed with multiple sclerosis after an in-depth work-up.

Cerebral angiogram failed to reveal the cause of the hemorrhagic stroke due to recurrent right frontal lobar hematoma in the patient with infective endocarditis. The patient did not have another intracranial bleeding episode and had an mRS of one at one month. This patient had symptoms of fever and tachypnea prior to cerebral angiography; however, chest FDCT was indeterminate.

The patient with ruptured Pcom aneurysm did not exhibit any symptoms related to probable COVID-19 pneumonia. He was Hunt-Hess grade four when he was taken to the angiography suite for intervention, he was intubated and in poor general medical condition before the procedure. The basic aneurysm coiling procedure went technically well. Towards the end of the procedure, he developed a transient and brief respiratory collapse which was attended by the anesthesiology team promptly and his vital findings were corrected within several minutes. He expired four days after the procedure secondary to the complications related to diffuse subarachnoid hemorrhage and secondary vasospasm. The reason for the transient ventilation problem that occurred during the procedure remained unknown.

None of the children with retinoblastoma had either pulmonary or procedure-related neurological or ophthalmological complication on follow-up. In one child, there was a transient decrease in oxygen saturation during the procedure, so FDCT was obtained as soon as the drop in the saturation was noticed. During the spin of the X-ray tube for FDCT, it became evident that the endotracheal tube was placed too distally in the mainstem bronchus (Figure 2), which was also verified on 3D images and immediately corrected, promptly restoring oxygen saturation. In the other two patients, there were no adverse events. None of the children exhibited signs or symptoms of COVID-19. However, in one of these children, there were ground glass opacities and areas of consolidation which were interpreted as indeterminate for COVID-19.

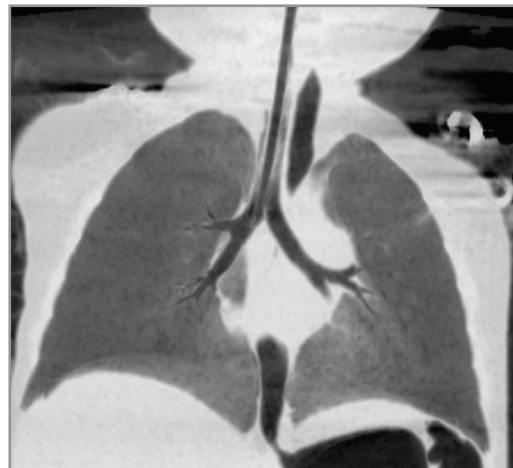


Figure 2. Coronal minimum intensity projection reformatting of chest flat-panel CT image reveals selective intubation of the right mainstem bronchus in a child with retinoblastoma.

Detailed chest FDCT findings for each patient are given in Table 1.

When lung parenchymal findings were considered, 1 (9.1%) patient had typical findings for COVID-19, whereas 4 (36.4%) patients had indeterminate, and 6 (54.5%) patients had none of the findings suggesting COVID-19. None of the patients were in the atypical RSNA category. The most common parenchymal finding was atelectasis (eight patients), followed by consolidation (five patients), pleural effusion (two patients) and pulmonary mass lesion (one patient). The patient with a pulmonary mass lesion presented with AIS, presumably due to coagulopathy secondary to the underlying malignancy. In this patient, a peripheral well-circumscribed lobulated mass lesion suggested a presumptive radiological diagnosis of primary lung cancer; however, the patient expired three days after the procedure precluding further clinical and pathologic evaluations. The only patient with typical findings of COVID-19 had areas of focal consolidation and patchy ground glass opacities on FDCT (Figures 1 A, B).

DISCUSSION

In this study, chest FDCT findings of COVID-19 patients were reported, the majority of FDCTs were obtained under general anesthesia. To our knowledge, this is the first study in the literature utilizing C-arm FDCT technology for dedicated thoracic imaging at the angiography suite. There are a few previous reports about the use of cone-beam CT used for thoracic imaging during the COVID-19 era in the literature (9-13). However, with the exception of a case report concerning thoracic imaging with a mobile cone-beam CT unit, these studies report utilization of cone-beam CT during radiotherapy (13). That is, all of them were performed in a non-interventional context, outside of the IR suite.

FDCT is a CT technology in which rows of detectors of standard multi-detector CT (MDCT) are replaced by a flat panel of detectors. This specific geometry of detectors allows the system to have wide z-axis coverage that enables to scan wide areas such as the cranium or abdomen in single rotation with a high spatial resolution (14). With its combined fluoroscopic and tomographic properties, FDCT systems can be incorporated to the C-arm gantry. Using such technology, C-arm FDCT systems have gained widespread use especially in routine interventional neuroradiology practice since it gives the operator

the ability to perform the endovascular procedure and obtain head CTs of the patient before or after the procedure within the angiography suite (15). Non-contrast head FDCT has been used in routine clinical practice to investigate possible perioperative intracranial hemorrhage for which emergent interventions may have immediate and life-saving consequences (16). In addition to investigating perioperative hemorrhagic complications, different studies suggested that FDCT can be used to evaluate ischemic changes among acute stroke patients with a reasonable degree of diagnostic accuracy compared to standard MDCT (17). Moreover, FDCT has a superior spatial resolution when compared to MDCT and this enables its users to evaluate more accurately intravascular devices such as stents and neighboring structures as well as small vessels and the cochlea (18,19).

The advent of the COVID-19 pandemic dramatically changed the workflow and patient algorithm in IR departments (20). It forced the administrators and healthcare professionals in charge to take further precautions in angiography departments in order to protect both the patients and the personnel working in the department from hazards of unexpected COVID-19 contamination. The use of FDCT in the angiography suite for non-neurologic applications was adopted by us during this time.

Documentation of COVID-19 positive status as early as possible in AIS, regardless of which laboratory or imaging modality is used, does not only bear importance in this patient subgroup as a predictor of worse prognosis, but it also has logistical significance (21-23). The usual AIS patients are transferred, mostly after extubation, to the neurological ICU, whereas the COVID-19 positive patient needs to be admitted to a specialized and dedicated COVID ICU in many institutions including ours.

In patients who have contracted contagious diseases like COVID-19, FDCT represents a further diagnostic test that helps the diagnosis or the extent of the primary disease. For instance, the main diagnostic modality, RT-PCR test, may be negative in patients who actually are diagnosed with COVID-19 later on. Ancillary tests like FDCT may provide additional data warranting further diagnostic work-up or patient isolation until a definitive diagnosis can be reached. The advantage of FDCT is that it is readily available in most of the angiography suites and can be applied

easily to patients who need emergency image-guided interventions that cannot be delayed while waiting for the results of other diagnostic laboratory tests. Furthermore, these patients who need emergency IR procedures usually need to be observed in postoperative care units or intensive care units. An unexpected positive finding related to an air-borne pathogen on FDCT may alert the medical staff and prevent undue spread of the disease in the hospital setting. As such, FDCT may potentially provide some of the information that is ordinarily provided by MDCT in selected cases or scenarios.

Two children with retinoblastoma had small focal areas of atelectasis on the chest FDCT. We speculate that the presence of atelectasis may be due to inadvertent right selective intubation in one child and clinically silent minor aspiration during induction of anesthesia in the other child. The third child had areas of ground glass opacities and consolidation on the chest FDCT. These findings in the first two children were not relevant to the COVID-19 pneumonia and they were indeterminate in the third child. They had no respiratory or neurological complications after the procedure on follow-up.

Apart from the retrospective design of the current study, there are limitations arising from the factors inherent in FDCT. First, motion artifacts pose great challenge for optimal diagnostic accuracy since imaging time (in our study 20 seconds) is longer than standard MDCT acquisitions (17). Shorter duration FDCTs in newer C-arms may provide images with similar diagnostic accuracy but this remains to be shown. Most of our patients underwent neurointerventional procedures with general anesthesia, and therefore, motion was generally not a problem in our patient cohort. There was some motion artifact secondary to the cardiac beat. However, possible detrimental effect of motion on the diagnostic quality of images has to be taken into account when performing FDCTs under conscious sedation or local anesthesia. Second, FDCT systems have an inferior contrast resolution when compared to MDCT (14). Although this may have a considerable impact over evaluation of focal lesions in solid viscera, its effect over the evaluation of pulmonary parenchymal findings of COVID-19 is questionable. Third, due to geometric magnifications, a 48 x 48 cm flat panel detector system corresponds to a much smaller field of view which is inadequate for full coverage of both lungs especially for overweight or tall adults. Finally,

atelectasis was the most common imaging finding in our patients, which is not unexpected, as small areas of atelectasis are quite common after general anesthesia. Collapsed lung tissue can be seen up to 90% of the patients because of muscle paralysis during general anesthesia (24). Furthermore, aspiration during and after induction of anesthesia and cerebrovascular disease resulting in swallowing difficulties can cause both atelectasis and pneumonia. Therefore, differential diagnosis of COVID-19 pneumonia or aspiration pneumonia can be challenging when the findings are indeterminate in these patients. Moreover, the presence of both consolidations and atelectasis can obscure the typical findings of COVID-19 pneumonia since lower and posterior areas of the lung are most commonly involved both by aspiration, COVID-19 pneumonia, and atelectasis (25). Negative radiological findings according to RSNA classification in 50 % of our patients may be due to mild involvement of the lungs and overlapping opacities of COVID-19 pneumonia with atelectasis.

CONCLUSION

In conclusion, during the COVID-19 era, IR patients with pulmonary symptoms suspicious for viral pneumonia or patients with accompanying clinical situations which make them more prone to complications of pulmonary infection may be scanned for thoracic findings of COVID-19 or similar disease processes with the help of flat-panel CT under emergency settings without undertaking a transfer of the patient from angiography table.

Ethical Committee Approval: This study was approved by Hacettepe University Faculty of Medicine Health Sciences Ethics Committee (Decision no: SBA 24/907 Date: 13.08.2024).

CONFLICT of INTEREST

The authors declare that they have no conflict of interest.

AUTHORSHIP CONTRIBUTIONS

Concept/Design: SB, OMA, AA

Analys/Interpretation: GD, OMA, EMA, AHK

Data acquisition: SB, MAT, AA

Writing: SB, GD, EMA, AHK

Clinical Revision: GD, OMA, MAT, AA

Final Approval: SB, OMA, AA

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