Optimization Of Contrast Media In Intracranial Ct Angiography

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Abstract

Iodinated contrast agent is widely used in intracranial CT to enhance the contrast between vascular structures and surrounding tissues. Its use allows for better visualization of pathologies involving the vascular system, such as aneurysms, arteriovenous malformations, venous thrombosis, and vascular flows. Additionally, it enables more precise identification of tumor lesions, metastases, and inflammation, where the disruption of the blood-brain barrier leads to increased accumulation of contrast in pathological areas.
Optimizing the radiation dose in intracranial CT is crucial to minimize the risk associated with exposure to X-rays while still maintaining sufficiently high image quality for accurate diagnosis. The proper optimization of contrast media in intracranial CT depends on multiple factors. We analyzed several cases in which CT angiography was performed, adhering to the factors that imply optimization while also following the fundamental rule of mathematical calculation to determine the appropriate amount of contrast agent, even in cases with low concentration where optimization of the IDR must be employed..

Introduction

The technological evolution of Computed Tomography (CT) in the last decade, with the development of multidetector CT (MDCT), has produced innovative acquisition and study techniques; one of the most effective is undoubtedly CT angiography (CT angiography). CT angiography can be defined as the acquisition of a body district during the arterial phase; hence, the scan must be performed at the peak vascular opacification phase, meaning when there is the maximum concentration of contrast agent within the arteries being studied. For optimal study, adequate venous access is necessary for rapid bolus injection of the contrast agent at a flow rate of 3-5 ml/sec (using 16 or 18 G cannula needles), with modern automatic injectors, followed by a bolus of saline solution, which helps maintain the compactness of the contrast bolus for a longer time, thus reducing total volumes..

Materials and Methods

Study Protocol
Patient Preparation:
The patients were selected using the same study method to optimize the quantity and flow of the contrast medium.
Abbiamo dunque utilizzato lo studio prospettico, monitorando l'uso del contrasto in tempo reale per avere risultati più accurati in pazienti di sesso maschile e/o femminile

Acquisition Sequences:
In CT scans, an X-ray tube rotates around the patient's body, emitting a thin beam of X-rays. A ring of radiation-sensitive detectors measures the intensity of the rays that have passed through the patient point by point. The characteristic of multi-slice CT (or multi-slice) is that it has multiple rings of detectors, allowing diagnostic information to be obtained for extensive regions of the body in a single scan, significantly reducing examination times. The first multi-slice CT scanners had 4 rings of detectors. Currently, there are scanners with 16, 64, 128, and even 320 slices. For this study, we used a 64-slice , performing an arterial phase to visualize the intracranial circulation

Development process Ct scans-64 slice – mdc
Where to monitor:
that is, the layer where we will position the Region of Interest (RoI) . Here's a clear example of the positioning of the ROI, using the Bolus Tracking monitoring system. It involves monitoring the enhancement and quickly starting the scan by utilizing a continuous measurement of attenuation in a small region of the vascular lumen being examined, where it is possible to select a threshold value (HU is the attenuation value, which, when exceeded or reached, triggers the scan; this value varies based on the examined regions and the acquisition speed.

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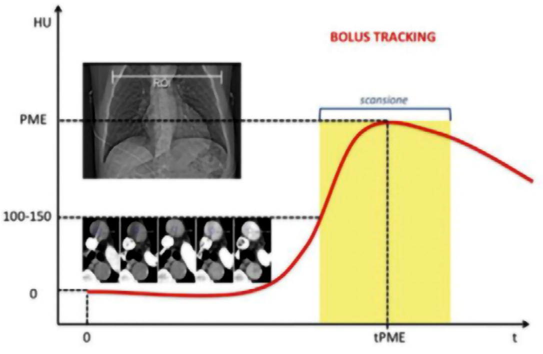
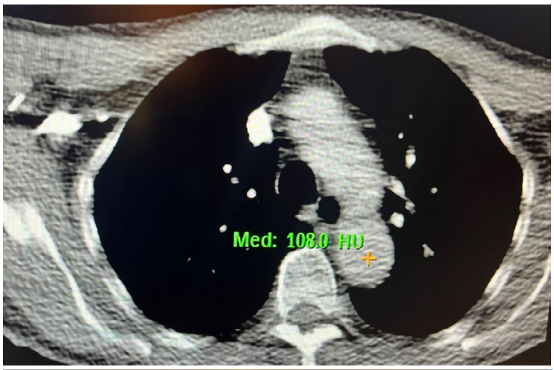
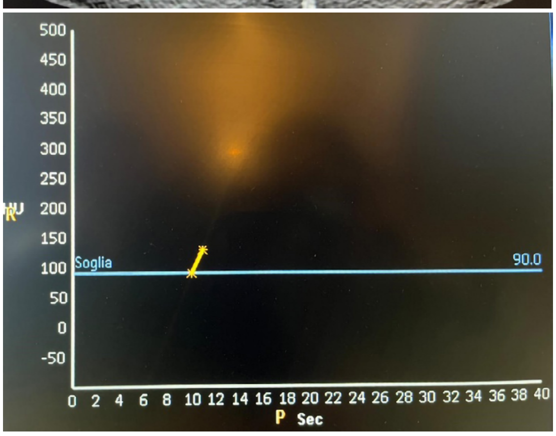
With faster equipment, it is advisable to set higher threshold values to avoid premature acquisitions with inadequate enhancement due to the bolus exceeding the limits). This allows for the automatic initiation of Angio-CT scans.







When to start monitoring:
that is, the delay for the first reference scan, In CT angiography exams, the minimum values (6-8 seconds) allowed by the equipment are set, which is the time required to position the X-ray tube-detector complex, dependent on its rotation speed and thus on its weight. This can be modified based on the acquisition time: in faster equipment, it can be increased to avoid acquiring too early relative to the peak enhancement; on the other hand, it should be minimized in slower equipment. Therefore, multiple parameters related to the following factors influence the quality of a CT angiography exam: scanning (duration, delays, timing); contrast agent (concentration, amount, speed and method of administration, saline solution); patient (cardiac output, weight, age, sex). However, it is primarily by adjusting only the modifiable parameters (delays, timing, speed of contrast agent administration) that the study protocol can be optimized according to the clinical question.

- **How much to monitor:** that is, the interval between reference scans (1 sec).

The scan must be performed during the PEAK PHASE OF VASCULAR OPACIFICATION. Venous access should be adequate for the injection of contrast media at a flow rate of 3-5 ml/sec (16-18 G), followed by a saline flush to "push" the residual contrast into the veins and improve image quality.

For this study method, we used a 64-detector multidetector CT scan. To ensure that we acquire the maximum density of the vessels in study, modern CT equipment is equipped with monitoring systems for the contrast media, which take into account three factors, depending on the anatomy being studied:

We aimed to understand how to obtain diagnostic images of cerebral arteries while optimizing the amount of contrast agent, thereby reducing the risk to the patient and costs. In this study, we analyzed various cases that differed from each other (including a vasospasm, a subarachnoid hemorrhage, an aneurysm, and various acquisition flows) that underwent CT angiography procedures, resulting in good image quality by adhering to the correct indications, protocols, mathematical formulas, and precautions to take during the practice of this procedure.

Results

Results obtained by using the mathematical formula to optimize the mdc applied to different cases under examination.

Patient with vasospasm:
Vasospasm is a narrowing of the cerebral arteries caused by the irritating effect exerted on the vessel walls by spilled blood. It can occur within a time frame ranging from a few hours to 3 weeks after the rupture of an aneurysm.

Patient with Subarachnoid Hemorrhage:
The location of the subarachnoid hemorrhage suggests a likely site of rupture of a cerebral aneurysm.

Patient with Aneurysm
Particular attention must be paid during the image reconstruction phase. In the case considered, in addition to the aneurysm responsible for the bleeding, there are two other aneurysmal dilatations.

Incorrect Technique vs Correct Technique
A scan acquired with too low an injection flow does not allow for proper vascular opacification of the arterial circulation in the intracranial space.

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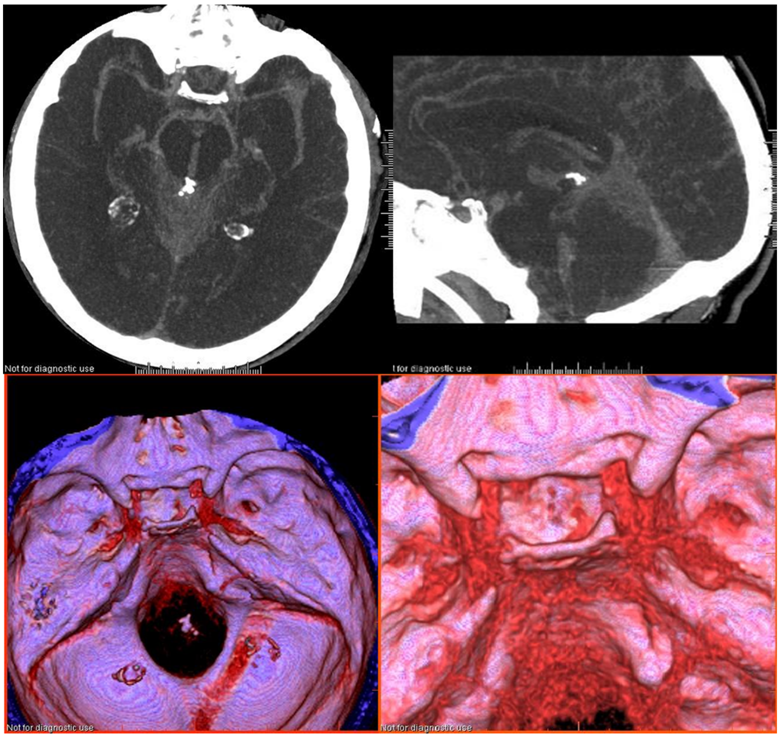
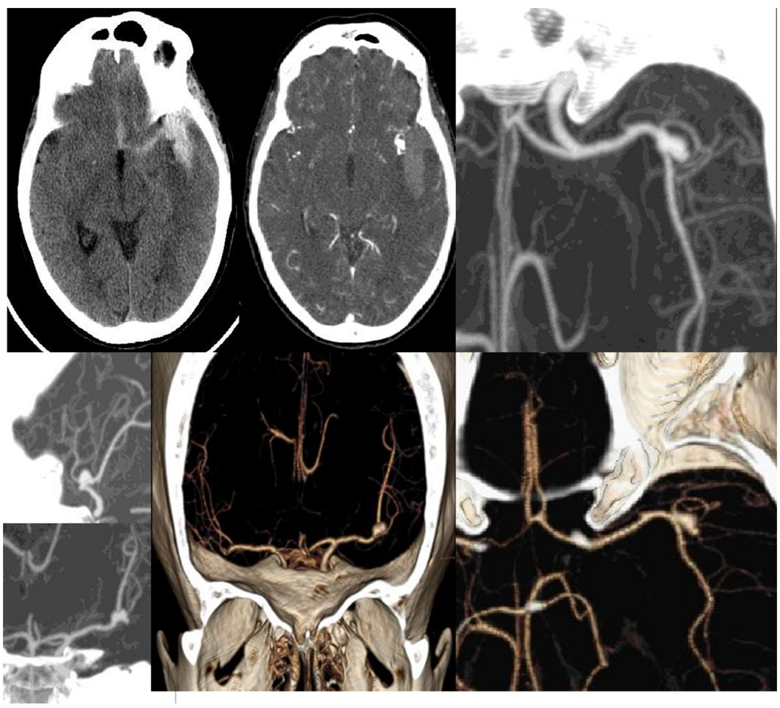


Fig.1 *The onset of vasospasm leads to a reduction in blood flow that normally supplies the brain tissue, potentially resulting in the appearance of ischemic areas.*
Scan Duration :7 sec
Delay :8 sec
Administration Technique of the Contrast Agent:
*Concentration: 350 mg/I*ml Injection flow rate: 4 ml/sec Quantity: 60ml*
*DLP:5576.99mGy*cm*



Figur 2: In the selected case, the blood accumulation is primarily concentrated in the subarachnoid space of the left sylvian artery.
Scan Duration: 5sec
Delay :5sec
Contrast agent administration technique:
*Concentration: 400 mg/I*ml Injection flow rate: 4 ml/sec Volume: 40 ml*
*DLP TOT : 3096.5 mGy*cm*

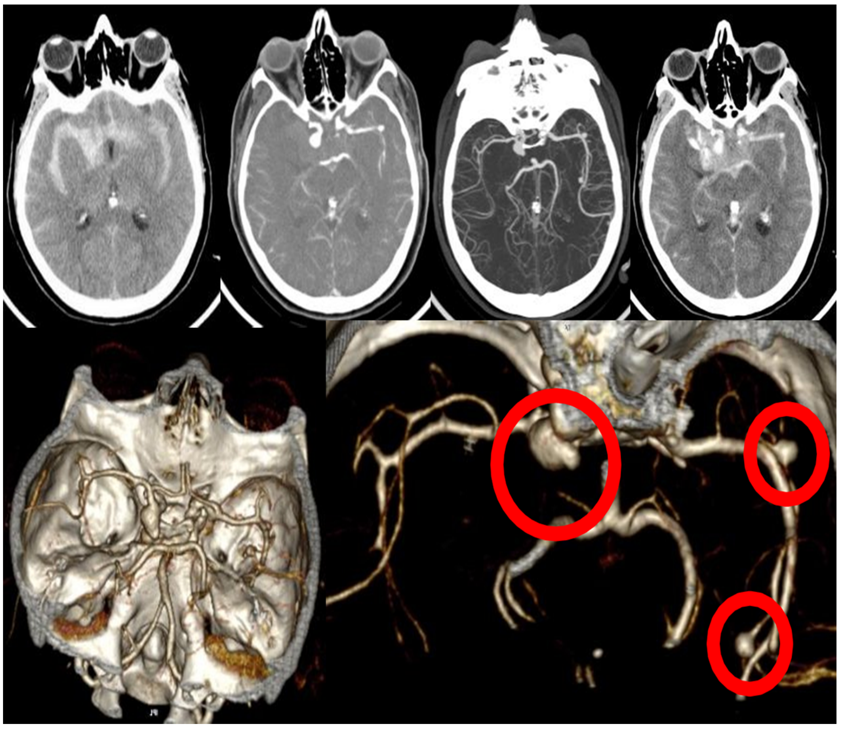


Fig 3 It is also useful to acquire a later phase to demonstrate the enhancement of the contrast medium.
Scan Duration: 5sec
Delay :5sec
*Contrast medium administration technique: Concentration: 320 mg/I*ml Injection flow rate: 5 ml/sec Quantity: 50 ml*
*DLP TOT :5.3 mGy*cm*

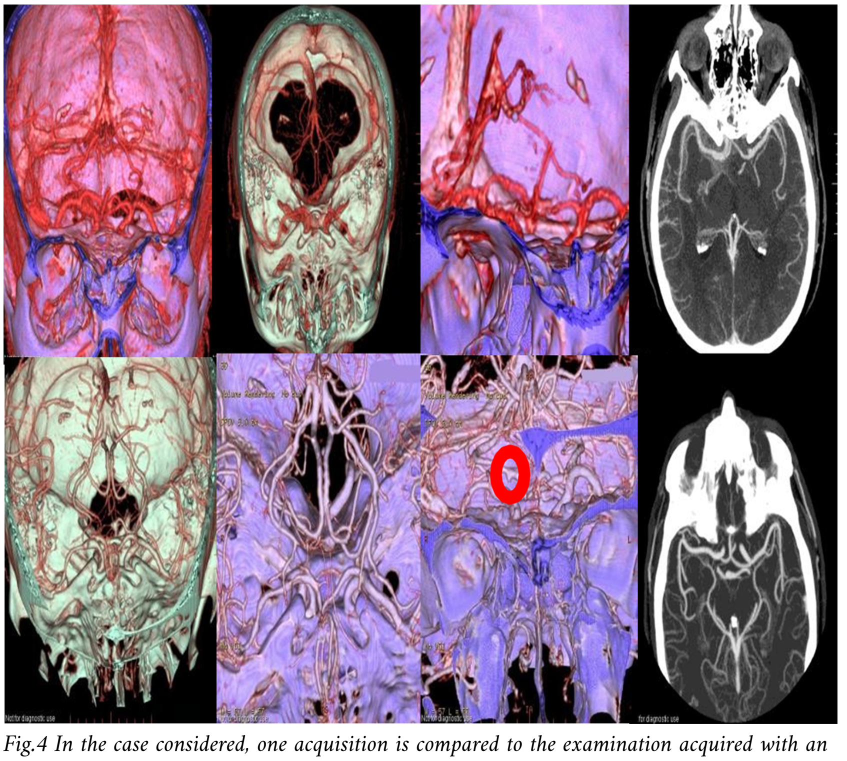


Fig.4 In the case considered, one acquisition is compared to the examination acquired with an injection flow of 1 ml/sec, contrasted with that related to the correct technique for administering the contrast agent.
Contrast agent administration technique:
Scan Duration:8sec
delay : 7sec
*Concentration: 370 mg/I*ml*
Injection flow: 1.5 ml/sec vs 3.5 ml/sec Quantity: 60 ml
*DLP TOT : 3096.5 mGy*cm*

Discussion

The amount of contrast agent administered is determined based on various factors, such as the type of study being performed. Generally, too low a dose may not provide adequate opacification of structures, while an excessive dose increases the risk of renal toxicity and other complications. In vascular studies, optimizing the amount of contrast agent cannot disregard three factors:

- Duration of the scan (D): Depends on the type of equipment available;
- Preparation time for the equipment (d): The time needed for the scanning system to align with the configuration required for acquisition;
- Injection flow rate of the contrast agent (F).

The relationship between these factors determines the adequate amount (Q) of contrast agent for the specific vascular scan, according to the formula:

$$Q = (D + d) * F$$

Example: For a scan lasting 5 seconds, with a preparation delay of 5 seconds, and an injection flow rate of 4 ml/sec, with a contrast concentration of 400 mg, the required amount will be:

$$Q = (5 + 5) * 4 = 40 \text{ ml.}$$

But not only that, how should one behave when a low iodine concentration contrast agent is available to achieve maximum opacification of the vessels? Would it be sufficient to increase the flow and consequently the quantity,
adhering to the mathematical formula for the optimization of the IDR (Iodine Delivery Rate)?

IDR = Concentration * Flow / 1000 1.6 = 320 * Flow / 1000 1.6 * 1000 / 320 = 5.3 (Flow) Thus, we would have a flow rate of 5.3. As the flow increases, the quantity also increases accordingly. However, it would also be advisable to use low Kv values to better highlight the structure.

Conclusions

In conclusion, the optimization of contrast agents in intracranial CT angiography represents a fundamental step to improve diagnostic quality and reduce risks associated with the use of contrast agents.
Through the analysis of existing protocols and the application of targeted strategies, it has been possible to identify key parameters that influence the distribution and effectiveness of contrast in brain tissues. Research has shown that adapting contrast agent doses, along with advanced acquisition techniques and image post-processing, can contribute to a more accurate detection of vascular changes, further improving therapeutic planning and patient follow-up. Moreover, the adoption of innovative technologies, such as artificial intelligence and real-time image processing, promises to make the examination even more efficient by reducing acquisition times and improving the patient experience. Finally, it is essential that such innovations are accompanied by a suitable training program for professionals in the field, so they can incorporate these techniques into their daily work. Only through a multidisciplinary approach and continuous review of clinical practices will it be possible to achieve the goals of optimizing the contrast agent in CT angiography, ensuring a safe, effective approach, and maximum benefit for patients.

CONCENTRATION	*INJECTION FLOW*	*SCANNING TIME*	*DELAY*	*FORMULA*	*QUANTITY OF CONTRAST MEDIUM*
350	*4 ML/S*	*8*	*7*	*6+6*4*	*60*
400	*4 ML/S*	*5*	*5*	*5+5*4*	*40*
320	*5 ML/S*	*5*	*5*	*5+5*5*	*50*
370	*4 ML/S*	*8*	*7*	*7+8*4*	*60*

(Summary table of the amount of contrast medium used in the listed examples, derived from the above- mentioned mathematical formula, based on the concentration of the contrast and the flow rate.)

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