Comparison of Fractionated vs Single bolus iodine contrast agent injection techniques in the CTA study of the Complete Aorta with 64-slices CT scanner. Preliminary results of the experience of the Radiographers/Nursing team of the Magliano Sabina Health House - ASL Rieti.

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Aorta aneurysm, computed tomography, Post Processing, contrast agent

Abstract

Introduction: *the technological evolution occurred in the last years of CT scanners , Contrast Agent molecules, analysis software and Vascular Post - Processing have allowed on the one hand to perform more and more dynamic Angio CT examinations with high Temporal Resolution but on the other hand they have imposed new technical challenges to the whole radiological team to optimize the study and try to obtain studies with suitable and homogeneous vascular enhancement throughout the Aorta. The ever-increasing Interventional Radiology, Vascular Surgery, and Interventional Cardiology activities involving the Aorta require increasingly optimal CT Angio imaging. Therefore it is important in order to have optimal CT Angio imaging that the enhancement is homogeneous from the aortic root up to the branch of the femoral a.femora in order to allow certain analysis and measurements over the whole volume studied. It is therefore important to acquire the examination with the most suitable tomographic technique, with the right volume administration of Contrast Agent, and with the most suitable injection technique in order to obtain optimal and homogeneous vascular enhancement throughout the Aorta*

Purpose: *the aim of our study is to compare and analyze two different Contrast Agent injection techniques in the CT study of the Complete Aorta to understand which one is more suitable to achieve homogeneous enhancement of the whole aorta using a 64-slice CT scanner. The two techniques we used are the Single Bolus Technique in which the injection of the Contrast Agent is done in a single bolus at a constant rate and the Fractionated Bolus Technique in which the injection of the Contrast Agent is done in two fractionated boluses (30% of the volume at 3.5ml/sec - 70 of the volume at 3.0ml/sec)*

Materials and Methods: *we examined a total of 30 patients (18M-60%/12F-40%) who had a Complete Aorta CTA examination from March 2023 to July 2024 (15 months) at the Magliano Sabina Health House Imaging Diagnostic Department of District 2 Salario Mirtense of the ASL of Rieti. The total study sample has a mean age of 65.83aa (+28.17/-25.83aa - median value 66aa), a mean height of 169.13cm (+17.87/-14.13cm - median value 170cm), a mean weight of 76.93Kg (+22.07/-21.93Kg - median value 75kg) and a mean BMI of 27.01 (+10.34/-6.18BMI/mean value 25.42BMI). The total study sample is divided into two study arms. The Experimental Arm in which we used the Fractionated Bolus Injection technique consisted of 15 patients (8M/7F) with mean age 66.06aa (+27.94/- 23.06aa - median value 65aa), mean height 167cm (+12/-12cm - median value 170cm), mean weight 74.13Kg (+20.9/-19.1kg - median value 75Kg) and mean BMI of 26.67 (+5.38/- 5.84 BMI - median value 25.39 BMI). The Control Arm in which we used the Single Bolus Injection technique consisted of 15 patients (10M/5F) with mean age 70.5aa (+12.5/-30.5aa - median value 67aa), mean height 173.5cm (+13.5/-18.5cm - median value 170cm), mean weight 82.5Kg (+16.5/-22.5kg - median value 80Kg) and mean BMI of 27.49 (+12.05/-6.04BMI - median value 25.45 BMI). The following variables were evaluated for each study sample:Volume of injected Contrast Agent, Homogeneity of enhancement ,Dose Leght Product (DLP), quality of VR-3D imaging. All Complete Aorta CT Angio studies were performed: with Philips Ingenuity 64-Slice equipment from Philips, Automatic 3-channel CT Exprès injector from Bracco and reconstructed with Philips IntelliSpace Portal WorkStation. For all examinations in our study, we used a nonionic Iodine Contrast Agent with concentration 400mgI/ml*

Conclusions: *the preliminary results of our study suggest how the use of Fractionated Bolus injection technique Iodine Contrast Agent in CT Angio study of the Complete Aorta with 64-Slice CT scanner is indicated and strongly indicated in patients with height ≥175cm to achieve homogeneous and optimized CT imaging throughout the Aorta.*

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Acronyms

CT: Computed Tomography
TR: Temporal Resolution
CTA: Computed Tomography Angiography
IR: Interventional Radiology
NaCl: Sodium Chloride (saline)
HU: Housfield Unit
ROI: Region of Interest
BMI: Body Mass Index
HR: Health Rate
MPR: Multi Planar Recostroction
CPR: Curved Planar Recostruction
MIP: Maximum Intensy Projection
VR: Volume Rendering
PACS: Picture Archiving and Communication System
AVA: Advanced Vessel Analysis

Introduction

The technological evolution that has occurred in recent years of CT scanners , Iodinated agent constrast molecules, analysis and Post - Vascular Processing software have allowed on the one hand to perform increasingly dynamic and high Temporal Resolution(TR) Computed Tomography Angiography (CTA) but on the other hand have imposed new technical challenges on the whole radiological team to optimize the study and try to obtain studies with suitable and homogeneous vascular enhancement throughout the Aorta. The ever-increasing Interventional Radiology (IR), Vascular Surgery, and Interventional Cardiology activities involving the Aorta require increasingly optimal CTA imaging [1]. In fact, the latest generation of Angiography devices whether mobile (C-arm) or Fixed are equipped with guidance software and Fusion Imaging [2] that use CTA imaging [3] and are of considerable importance for successful procedures.

In the CTA study of the Aorta, therefore, it is important to acquire optimal imaging with homogeneous iodine agent contrast enhancement from the aortic root to the femoral artery branch in order to allow certain analysis and measurements over the entire volume studied. Of particular importance is the maintenance of optimal enhancement at the level of the femoral as these are the most commonly used endovascular access route in RI procedures.

Over time, numerous studies have analyzed CTA imaging of the Aorta comparing different methodologies and techniques of agent contrast injection. [4,6]. In our work, we compared two agent constrast injection techniques (Fractionated bolus va Single bolus) in the CTA of the Complete Aorta.

The purpose of this work was to compare two agent contrast injection techniques (Fractionated bolus vs Single bolus) in the CTA study of the Complete Aorta in order to optimize vascular enhancement. To this end, we created two study arms for observation:

- An experimental arm in which we performed Aorta CTA examination with fractional agent constrat injection technique (30% of volume injected at 3.5ml/sec - 70% of volume injected at 3ml/sec followed by a bolus of 25ml NaCl)
- A control arm in which we performed Aorta CTA examination with Single Bolus agent contrast injection technique (volume of MdC injected as a single solution at 3.5ml/sec followed by 25ml of NaCl)

Therefore, the main objective of our work was to evaluate the advantages, benefits, and possible limitations that the use of the Split Bolus Fractional Injection technique can bring in terms of optimizing vascular enhancement in the Complete Aorta CTA examination using a 64-layer CT scanner. Complete Aorta CTA examinations in all patients forming our study were acquired with homogeneous examination and scanning protocol that we will describe below in the Materials and Methods section.

The variables we will analyze for each sample are:

- Enhancement values along the course of the Aorta after introduction of agent constrast by detecting HUs in different anatomical locations with appropriate ROIs
- Quality of 3D imaging according to the rating scale described in the Materials and Methods section

Materials And Methods

To carry out our study, we examined a total of 60 patients (36M-60%/24F - 40%) who had a Complete Aorta CTA examination from March 2023 to July 2024 (15 months) at the Magliano Sabina Health House Imaging Diagnostic Department of District 2 Salario Mirtense of the ASL of Rieti. The entirety of the study sample had a mean age of 65.83years (+28.17/-25.83 years - median value 66 years), a mean height of 171.13cm (+17.87/-14.13cm - median value 170cm), a mean weight of 75.93Kg (+22.07/-21.93Kg - median value 75kg) and a mean BMI of 27.01 (+10.34/- 6.18BMI/mean value 25.42BMI). All patients included in the study had a Heart Rate (HR) between 60 and 80bt/min at rest.

All CTA studies were performed:

- with Philips Ingenuity 64-Slice equipment from Philips in the service [7]
- with Automatic 3-channel CT Exprès injector from Bracco [8]
- reconstructed in Post Processing with WorkStation IntelliSpace Portal from Philips [9]

The total study sample is divided into two study arms (Table 1):

- Experimental Arm: 30 patients (16M/14F) with mean age 65.06 years (+27.94/-23.06 years - median value 65 years), mean height 169 cm (+12/-12cm - median value 170cm), mean weight 74.13Kg (+20.9/-19.1 kg - median value 75Kg) and mean BMI of 25.67 (+5.38/-5.84 BMI - median value 25.39 BMI) and heart rate between 60 and 80bt/min. Patients in the Experimental Arm underwent Complete Aorta CTA

during the observation period with the study protocol described in Fig.1 [10] using the Split fractionated agent contrast injection technique (30% of volume injected at 3.5ml/sec - 70% of volume injected at 3ml/sec followed by a 25ml bolus of NaCl)

- Control Arm: 30 patients (20M/10F) with mean age 69.5 years (+12.5/-30.5 years - median value 67 years), mean height 172.5cm (+13.5/-18.5cm - median value 170cm), mean weight 82.5Kg (+16.5/-22.5kg - median value 80Kg) and mean BMI of 26.79 (+12.05/-6.04BMI - median value 25.45 BMI) and heart rate between 60 and 80bt/min . Patients in the Experimental Arm underwent Complete Aorta CTA during the observation period of the study with the study protocol described in Tab.1 [10] using the Single Bolus agent contrast injection technique (volume injected in a single solution at 3.5ml/sec followed by 25ml of NaCl)

Experimental sample		Control sample	
30 patients (16 male;14 female)		30 patients (20male;10 female)	
mean age	65.06 years (+27.94/-23.06)	mean age	69.5 years (+12.5/-30.5 years)
mean height	169 cm (+12/-12cm)	mean age	172.5cm (+13.5/-18.5cm)
mean weight	74.13Kg (+20.9/-19.1 kg)	mean weight	82.5Kg (+16.5/-22.5kg)
BMI	25.67 (+5.38/-5.84)	BMI	26.79 (+12.05/-6.04)
heart rate	between 60 and 80bt/min	heart rate	between 60 and 80bt/min

Fig. 1: *Summary description of the main characteristics of the two samples in our study* (*Source*: *Authors of the study*)

Tab.1: *CTA Aorta protocol used our study* (*Source*: *authors' self-produced image*)

1. *Surview AP-LL*	• *Leght*: 80-90*cm* • *Kv*: 80-90 • *MA*:30
2.*Basal CT acquisition*	• *Scanning from 3 cm above the arch of the aorta to 2-3 cm below the small trochanters of the femurs* • *Collimation*. 64x0.625*mm* • *Pitch*:1.2 • *Kv*: 120 • *mAs medio*: 160 • *Index Dose Rate*:17 • *Index Dose Rate Liver Area*: +2 • *Thickness IR*: 1,5*mm* • *Index IR*: 0,75*mm* • *Filter*:*Smooth* • *WL*:C60 *W*350
3.*Bolus Tracking*	• *ROI placed in ascending aorta with 150HU threshold and 3-second delay*
4.*CTA acquisition*	• *Scanning from 3 cm above the arch of the aorta to 2-3 cm below the small trochanters of the femurs* • *Collimation*. 64x0.625*mm* • *Pitch*:0.9 • *Kv*: 80- 100 • *mAs medio*: 250-270 • *Index Dose Rate*:17 • *Index Dose Rate Liver Area*: +2 • *Thickness IR*: 1*mm* • *Index IR*: 0,5*mm* • *Filter*:*Smooth* • *WL*:C60 *W*350
5.*Post Processing*	• *2D MPR/CPR reconstructions, 3D Maximum Intensity Projection reconstructions, Volume Rendering with subtraction of bone structures and bone in transparency, targeted measurements*

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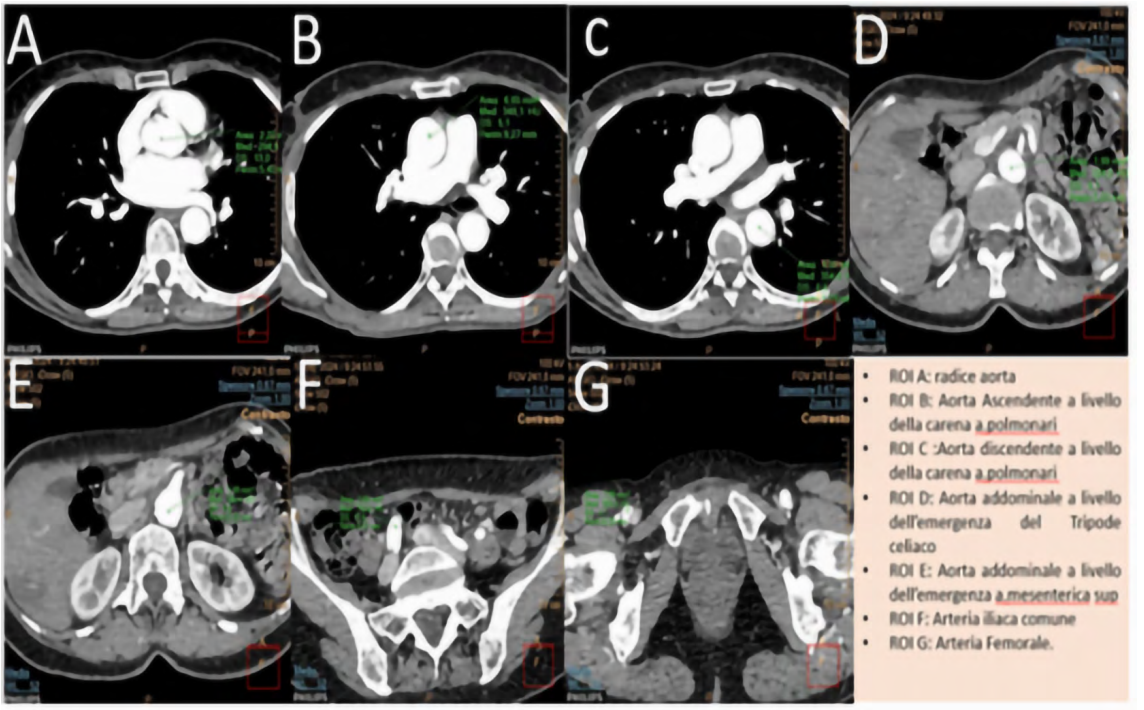
The following variables were evaluated for each study sample:

- Homogeneity of MoC enhancement expressed in UH and detected with appropriate ROIs in post - processing in different anatomical retrievals in CTA images after MoC introduction. In the Specific, the ROIs were placed in the following anatomical landmarks (Picture 1):
  - » ROI A: Aortic Root
  - » ROI B: Ascending Aorta in the CT image in which the branch of the pulmonary arteries is visualized
  - » ROI C: Descending aorta in the CT image in which the branch of the pulmonary arteries is visualized
  - » ROI D: Abdominal aorta in the CT image in which the emergence of the celiac tripod is visualized
  - » ROI E: Abdominal aorta in the CT image in which the emergence of the superior mesenteric artery is visualized
  - » ROI F: Common iliac arteries
  - » ROI G: Femoral arteries

- Evaluation of VR Imaging Quality - 3D . For each CTA Aorta Complete reconstructed the arterial phase images with the Volume Rendering HR Angio Algorithm of the Philips Workstation IntelliSpace Portal 9.0 AVA software [8] supplied to the Diagnostic Imaging service of the Magliano Sabina Health House. For each patient, we made a VR and saved a set of 10 images with a counterclockwise rotation of 10° between images. We anonymized the images and rated the imaging quality according to the rating scale described in Picture 2.

In picture 3 summarizes the scheme of our work with a Flow-Chart.



Picture 1: *Enhancement homogeneity assessment protocol that we used in the analysis of the Complete Aorta CTA examinations of our study* (*Source*: *Authors' self-produced image*)

3D-CT AORTA COMPLETE IMAGING RATING SCALE				
	NOT DISPLAYABLE	VIEWABLE IN SECTIONS	GOOD VIEWING	OPTIMUM VISUALIZATION
ASCENDING AORTA	0	1	2	3
SUPRA-AORTIC EMERGENCES	0	1	2	3
SUBCLAVIAN ARTERIES	0	1	2	3
CAROTID ARTERIES	0	1	2	3
DESCENDING THORACIC AORTA	0	1	2	3
CELIAC TRIPOD	0	1	2	3
EMERGENCY MESENTERIC ARTERY	0	1	2	3
MESENTERIC ARTERY BRANCHES	0	1	2	3
RENAL ARTERIES	0	1	2	3
INFERIOR MESENTERIC ARTERY EMERGENCY	0	1	2	3
ILIAC ARTERIES	0	1	2	3
INTERNAL ILIAC ARTERIES	0	1	2	3
FEMORAL ARTERIES	0	1	2	3

Picture 2: 3D imaging rating scale of VR-3D images of Aorta CTAs used by the Radiology Physicians who collaborated in our study (Source: Authors' self-produced image)

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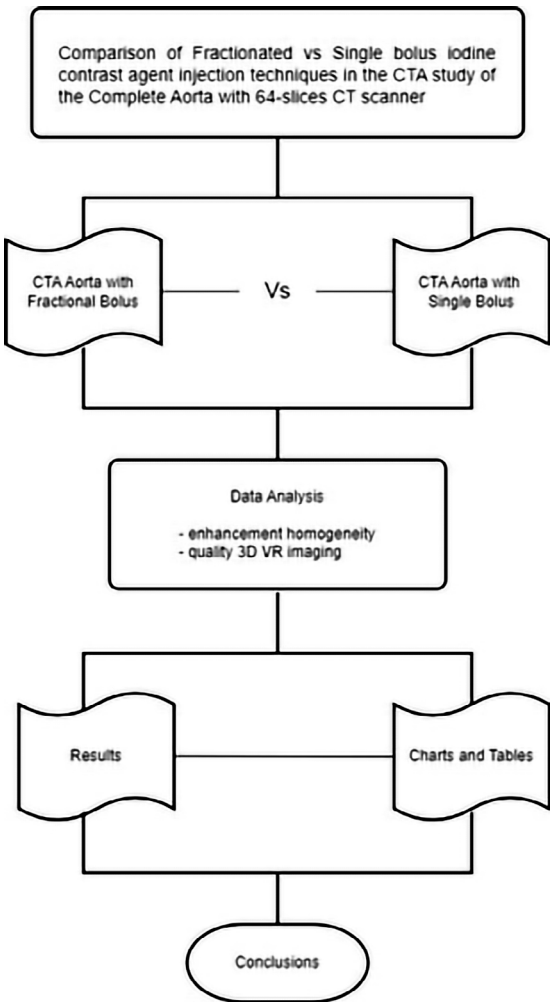
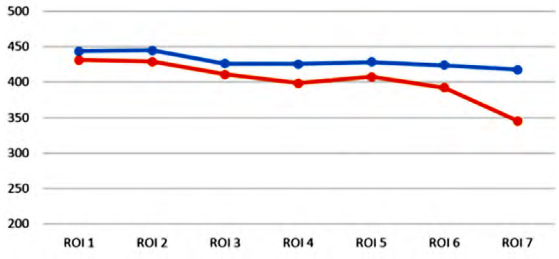


Picture 3: *Flow-Chart Summary of the pattern of our work* (*Source*: *self-produced image by the authors*)

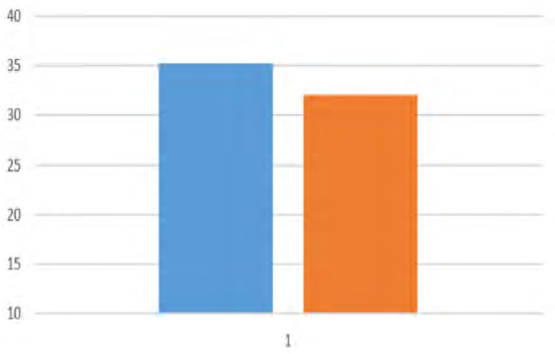
For data collection and recording, we used Excel spreadsheets [11] in which we recorded the patients' master data, weight, height, BMI, type of examination performed, the agent contrast used, and the volume injected. We recorded the coordinates of each individual study to recall it from the PACS during analysis. We then proceeded to divide the overall database into 2, one for each arm of our study and anonymized the databases by assigning each patient a code.

We then proceeded to the stage of analyzing the images for each individual patient with the protocols described above and through special excel spreadsheets recorded them. Finally, we made to make the Results of our study more readable tables and graphs.

Results



Picture 4 - *Line graph of the comparison of the average Enhancement Curves* (*Blue Fractional Bolus, Orange Single Bolus*) *detected in our study groups* (*Source*: *study authors*)



Picure 5 - *Histogram graph comparing the averages of the 3D imaging ratings in the two arms of our study, in Light Blue the Experimental Arm and in Orange the Control Arm* (*Source*: *study authors*)

Discussion

The evaluation of enhancement homogeneity in the Complete Aorta CTAs showed us clearly how the enhancement curves we recorded in the patients in whom we used the Fractionated Bolus technique are more homogeneous and with an average height above 450 HU. Interesting then is the finding regarding the last 3 ROIs examined, which are those most distal from the scanning motion. In fact, in the patients in whom we used the Fractionated Bolus technique we recorded how the curves at these 3 points are more homogeneous and uphill (Picture 5). In contrast, in the patients in whom we used the Single Bolus technique, we recorded lower curves with an average of 395 HU but especially a descent of enhancement at the distal points of the scan, which are those affected by the iliac and femoral arteries (Picture5). This finding is important as proper visualization of the iliac and femoral arteries is now indicated by all guidelines as these arteries are the most widely used access routes for RI, Endovascular Surgery and Interventional Cardiology procedures. These data were then clearer in patients exceeding 175cm in height, in fact comparing 6 patients in the Experimental Arm with height ≥175cm with as many patients with the same characteristics in the Control Arm we noticed that especially in the distal regions of the scan with the Fractionated Bolus technique there is greater enhancement homogeneity while with the Single Bolus technique a more pronounced fall in the enhancement curve.

The analysis of the quality of VR - 3D imaging of Angio-CT performed documented for us an average rating of the same of 35.2 in patients in whom we used the Fractionated Bolus technique and 32.07 in patients in whom we used the Single Bolus technique (Picture 6). This finding is, in our opinion, strongly related to the higher homogeneity of enhancement detected in the Experimental Arm of our study.

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These data are in the nature of entirely preliminary results because:

- our study is at an early stage,
- because of the still low number of patients
- we carried out the study in a single center

Therefore, the data needs a further period of study and observation to be confirmed. Nonetheless, the preliminary indications that the results we recorded documented are in our opinion clear especially regarding the homogeneity of enhancement which, with the use of the fractionated bolus injection technique, is significantly better using 64-Slice CT scanners.

Conclusions

The results of our study, albeit preliminary, documented to us a better homogeneity of enhancement in CTA Aorta Complete examinations using the Fractionated Bolus injection technique. In fact, the best enhancement recorded in examinations in which we used this technique to optimize agent contrast injection coupled with the best 3D imaging recorded give us as a clear indication that the use of the aforementioned injection technique, using 64-Slice CT scanners, is indicated in Complete Aorta CTA examinations and strongly indicated in patients with height ≥175cm. This is because the best enhancement we have documented in patients in whom we used the Fractionated Bolus injection technique allows for optimal and homogeneous documentation of the entire Aorta from the root to the femoral branch and, most importantly, greatly decreases the drop in enhancement in the distal areas of the scan

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