MEDICAL SCIENCE

Comparative study of automatic bolus tracking and manual bolus tracking in triphasic Computed Tomography of the abdomen

Amal Shaji[1], **Adarsh KM**[2], **Amita Digambar Dabholkar**[3*]

To Cite:
Shaji A, Adarsh KM, Dabholkar AD. Comparative study of automatic bolus tracking and manual bolus tracking in triphasic Computed Tomography of the abdomen. *Medical Science* 2023; 27: e321ms3107.
doi: https://doi.org/10.54905/disssi/v27i138/e321ms3107

Authors' Affiliation:
[1]MSc., MIT, Yenepoya (Deemed to be university), Yenepoya School of Allied Health Sciences, Department of Radiodiagnosis and Medical Imaging, Mangalore, Karnataka, India
[2]Associate Professor, Yenepoya (Deemed to be university), Yenepoya Medical College, Department of Radiodiagnosis and Medical Imaging, Mangalore, Karnataka, India
[3]Assistant Professor, Yenepoya (Deemed to be university), Yenepoya School of Allied Health Sciences, Department of Radiodiagnosis and Medical Imaging, Mangalore, Karnataka, India

[*]Corresponding author
Assistant Professor, Yenepoya (Deemed to be university), Yenepoya School of Allied Health Sciences, Department of Radiodiagnosis and Medical Imaging, Mangalore, Karnataka,
India
Email: dabholkaramita99@gmail.com
ORCID: 0000-0001-9603-8422

Peer-Review History
Received: 07 June 2023
Reviewed & Revised: 10/June/2023 to 22/July/2023
Accepted: 26 July 2023
Published: 03 August 2023

Peer-review Method
External peer-review was done through double-blind method.

Medical Science
pISSN 2321–7359; eISSN 2321–7367

ABSTRACT

Background: A computer-assisted bolus tracking system that initiates diagnostic scans prompted by contrast enhancement was recently developed. Using low-dose scans, this technology allows the scans to start, either manually or automatically, when the contrast enhancement rises to a predefined threshold (ROI). We aimed to compare the automatic bolus tracking and manual bolus tracking triphasic contrast enhancement in the abdomen. *Materials and Methods:* To compare automatic bolus tracking and manual bolus tracking method for contrast enhancement in the Hounsfield Unit of abdominal vessels and measure the delay in contrast enhancement in automatic and manual bolus tracking methods. The studies were conducted in the Department of Radio-diagnosis. 72 participants were included in the study that underwent triphasic CECT abdomen. *Results:* The Thoracic Aorta (HU) and Abdominal Aorta (HU) of the two groups differ significantly (P value 0.001). There is a substantial difference between the two groups in Hepatic Artery (HU) and Delay Time (S) (P value 0.001). *Conclusion:* This study revealed that automatic bolus tracking was the most beneficial approach in triphasic CECT Abdomen when compared to manual bolus tracking.

Keywords: Computed Tomography, Bolus tracking, Automatic bolus tracking, Manual bolus tracking, Triphasic Abdomen, Hounsfield Unit

1. INTRODUCTION

An imaging technique called computed tomography (CT) creates cross-sectional images that show the X-ray attenuation characteristics of anatomical structures. With the introduction of intravenous contrast delivery, CT has continued to advance. A class of medications known as radiographic contrast media is used in CT scans to increase the visibility of internal organs and structures (Suetens, 2002). Contrast material leaves the peripheral intravenous system and travels to the right heart, pulmonary circulation, and left heart before arriving at the central arterial system. Its circulation throughout the body is regulated by the cardiovascular system (Bae, 2010).

The circulatory system of the organs quickly redistributes contrast media to the interstitial spaces. The blood dilutes the contrast medium as it circulates in the body, and the bolus diffuses as it passes through the circulatory system. Ionic, nonionic, monomeric, and dimeric iodine-based contrast media are typically employed to visualize blood arteries, tissues, organs, and the urinary tract (Andreucci et al., 2014).

They aid in distinguishing between healthy and infected regions. Generally speaking, they are risk-free, and side effects are typically modest and self-limiting. Optimizing contrast enhancement of the liver using conventional CT has been studied extensively with the goal of improved detection of hepatic lesions. Iodinated contrast substances have been shown to improve lesion detection, but controversy remains as to the optimal rate and timing of scanning relative to contrast administration (Silverman et al., 1995). A recently designed computer-assisted bolus tracking system that initiates diagnostic scans automatically in response to contrast enhancement. This method, which employs low-dose scans, enables scans to begin, either manually or automatically, when the contrast enhancement reaches a specified threshold (ROI) (Bae et al., 2008).

A newly designed, automated hardware and software development, Smart Prep allows one to monitor contrast enhancement on scans during the early stages of contrast injection. A sequence of rapidly recreated low-radiation-dose assessment scans are used in the procedure. Regions of interest (ROIs) of target structures (liver, aorta, portal vein) are displayed graphically and numerically, tracking their enhancement during the contrast administration (Bae et al., 2007). Individual variations regarding body weight, Heart rate variability, circulation duration, and cardiac abnormalities can all affect the time frame as well as the necessary rate and volume of contrast material, making it difficult to achieve optimal contrast enhancement (Brink, 2003).

The level of contrast enhancement is largely proportional to a patient's body weight and the quantity of contrast agent used. If constant contrast enhancement is needed, the amount of iodine supplied should be adjusted based on the patient's body weight. A large patient needs more iodine than a small patient to achieve the same magnitude of enhancement (Silverman et al., 1995). When a desired level of enhancement is reached for a particular structure; a transition is made to the routine diagnostic helical imaging series. This method provides a mechanism by which the time of scan initiation can be individualized based on the actual enhancement of anatomic structures rather than on an arbitrary delay time (Kopka et al., 1995).

Using a standard delay time following the onset of contrast administration ignores the varied transit times of the contrast bolus across patients. The density of a region of interest (ROI) and hence the contrast enhancement can be evaluated via automatic bolus monitoring, and a biphasic helical CT scan is optimised for individuals. The contrast enhancement achieved in response to an injection of contrast material is related to the amount of iodine that is deposited in the target fluid or tissue (Adibi and Shahbazi, 2014). With this background, the current study is aimed to compare the automatic bolus tracking and manual bolus tracking triphasic contrast enhancement in the abdomen.

2. MATERIALS AND METHODS

Study population

This descriptive study was approved by Yenepoya ethical committee after the approval from scientific review board and all patients provided informed consent before participation in the study. The studies were conducted from department of radio diagnosis, Yenepoya medical college hospital, Mangalore between November 2022 and April 2023. 72 (estimated based on the) participants who satisfied the following requirements for inclusion were included, that were age group between 20-80 years and patients who were undergoing triphasic CECT abdomen. The patients who have had a history of contrast allergy, severe history of heart diseases and pregnant women were excluded from this study. By using simple random selection, the 72 participants were categorized into two groups, automatic bolus tracking and manual bolus tracking. Each group had 36 individuals.

Imaging Protocol and analysis

Using a sterile technique, the contrast was given by a pressure injector which was controlled by the technologist. There was any possible harm, side effects, or adverse effects found. 70 ml of non-ionic contrast media was given at the rate of 2.7 ml/s by pressure injector (same for automatic bolus tracking and manual bolus tracking). The contrast media which was selected for the study contains 350 mg I/ml (iodine content) strength. Average radiation exposure for the triphasic CECT abdomen was 1966 mGy/cm DLP (Dose length product). Adult patients underwent contrast-enhanced abdominal triphasic scans were categorized into two groups based on simple random sampling.

In group 1, plain abdominal scans were taken. Pre-contrast density was determined by calculating HU from the aorta and hepatic artery. Patients were scanned for tri-phase (arterial, portal-venous, and venous phase) automatic bolus tracking. The tracker had been kept on the aorta and contrasts were given through a pressure injector. Dynamic studies were selected, where the scan starts at a level of 80HU threshold i.e., when contrast reaches the aorta. After scan ends, contrast enhancement was calculated with help of HU ROI.

In Group 2, plain abdominal scans were taken. Pre-contrast density was determined by calculating HU from aorta and hepatic artery. Patients were scanned with tri-phase (arterial, portal-venous, and venous phase) manual bolus tracking. The tracker had been kept on the aorta and contrasts were given through pressure injector. With the help of graph and time when contrast reaches the aorta, the scan phase had obtained. After scan ended, contrast enhancement was calculated with the help of HU ROI. Group 1 and Group 2 were compared based on the contrast enhancement in thoracic aorta, the abdominal aorta and the hepatic artery.

Statistical analysis

For statistical analysis, in Descriptive statistics Mean and standard deviation for continuous data and Frequency and percentage for categorical data independent sample t–test and Mann-Whitney test was used to compare automatic bolus tracking and manual bolus tracking

3. RESULTS

This study consisted total of 72 patients. Sample collected from the period of November 2022 to January 2023 satisfying the inclusion and exclusion criteria, which were further divided into two groups. Automatic bolus tracking and Manual bolus tracking with 36 patients in each group. The numbers of females were 36% (13 females) and males were 63% (23 males) in automatic bolus tracking group and manual bolus tracking group included females were 50% (18 females) and males were 50% (18 males) (Table 1).

Table 1 Descriptive statistics of automatic bolus tracking and manual bolus tracking

						Shapiro-Wilk	
	Group	N	Mean	Median	SD	W	p
Thoracic Aorta (HU)	ABT	36	371.36	367.50	17.09	0.970	0.422
	MBT	36	346.69	350.00	17.03	0.950	0.107
Abdominal Aorta (HU)	ABT	36	363.75	361.50	16.74	0.948	0.093
	MBT	36	341.75	344.50	16.26	0.963	0.257
Hepatic Artery (HU)	ABT	36	306.42	305.50	8.79	0.938	0.043
	MBT	36	272.86	270.00	21.44	0.767	< .001
Delay Time (S)	ABT	36	7.17	7.00	1.00	0.863	< .001
	MBT	36	13.72	14.00	1.50	0.878	< .001

*ABT - automatic bolus tracking
*MBT - manual bolus tracking

Table 1 shows that among the thoracic aorta, the mean HU in automatic bolus tracking was 371.36HU (SD – 17.09) and in manual bolus tracking the mean HU was 346.69HU (SD – 17.03). The mean HU for automatic bolus tracking and manual bolus tracking in the abdominal aorta was 363.75HU (SD – 16.74) and 341.75HU (SD – 16.26) respectively. Among the automatic bolus tracking the mean HU for the hepatic artery was 306.42HU (SD – 8.75) and in manual bolus tracking the mean HU was 272.86HU (SD – 21.44). In delay timing among the automatic bolus tracking was 7.17 seconds (SD - 1) and the delay time among the manual bolus tracking was 13.725 seconds (SD - 1.50) (Figure 1) (Table 2).

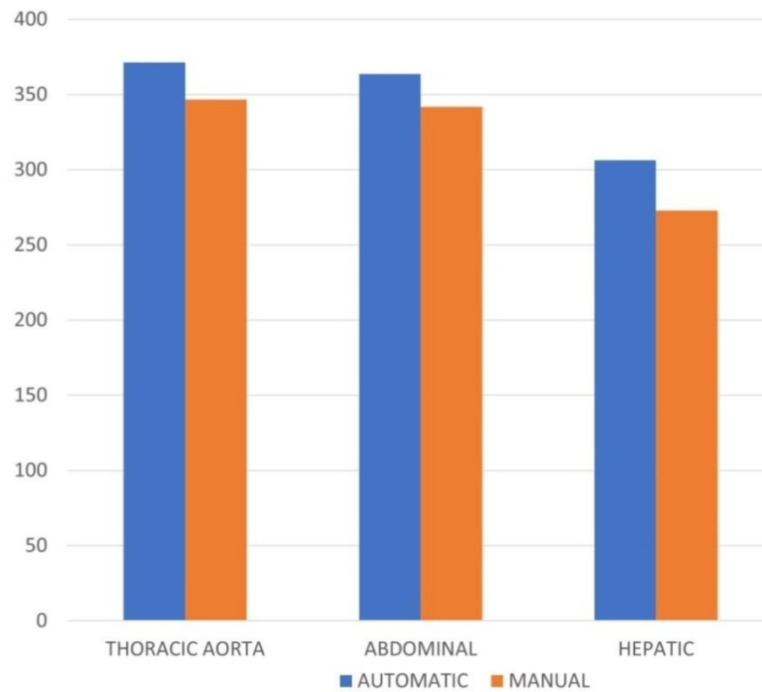

Figure 1 Bar diagram (HU enhancement in both automatic and manual bolus tracking)

Table 2 Descriptive Statistics of automatic bolus tracking

	N	Minimum	Maximum	Mean
Thoracic Aorta (HU)	36	329	402	371.36
Abdominal Aorta (HU)	36	312	391	363.75
Hepatic Artery (HU)	36	291	325	306.42
Delay Time (S)	36	6	9	7.17

It shows that, the groups of automatic bolus tracking and manual bolus tracking were compared between thoracic aorta and abdominal aorta using an independent sample t-test, and there was a significant difference between the two groups in Thoracic Aorta (HU) and Abdominal Aorta (HU) (P value <0.001) (Figure 2A, 2B).

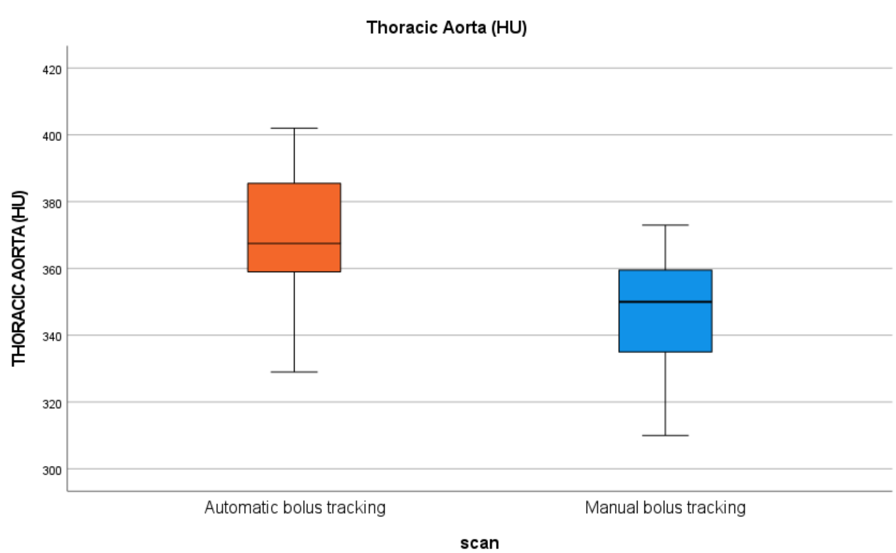

Figure 2A Thoracic aorta enhancement in automatic bolus tracking and manual bolus tracking

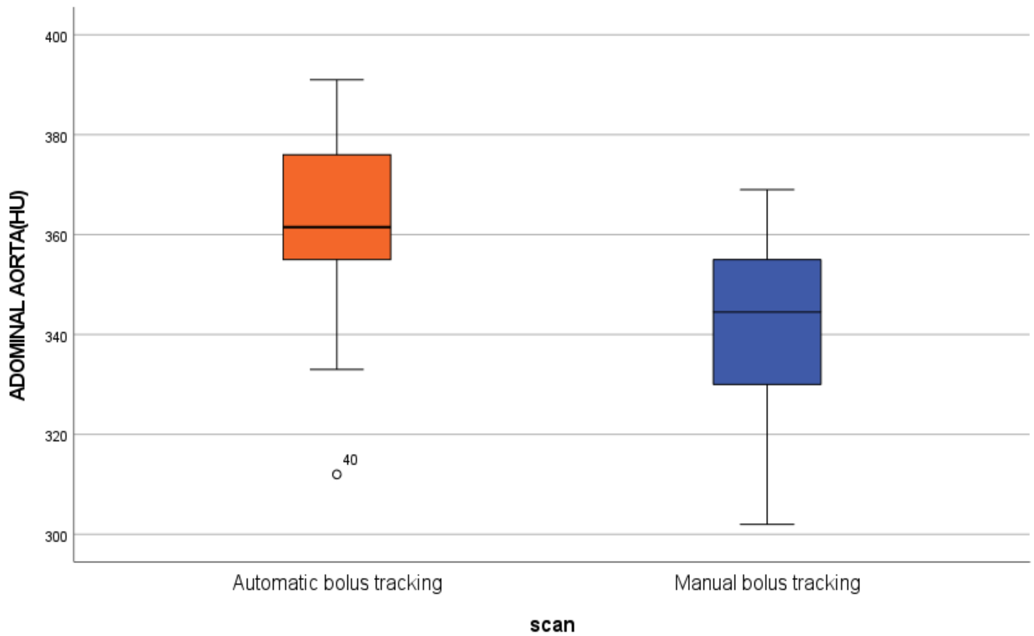

Figure 2B Abdominal aorta enhancement in automatic bolus tracking and manual bolus tracking

There was a significant difference in Hepatic Artery (HU) and Delay Time (S) of two groups (P value <0.001). The Mann Whitney U test was used to compare Hepatic Artery (HU) and Delay Time (S) among two groups (Figure 3A, 3B).

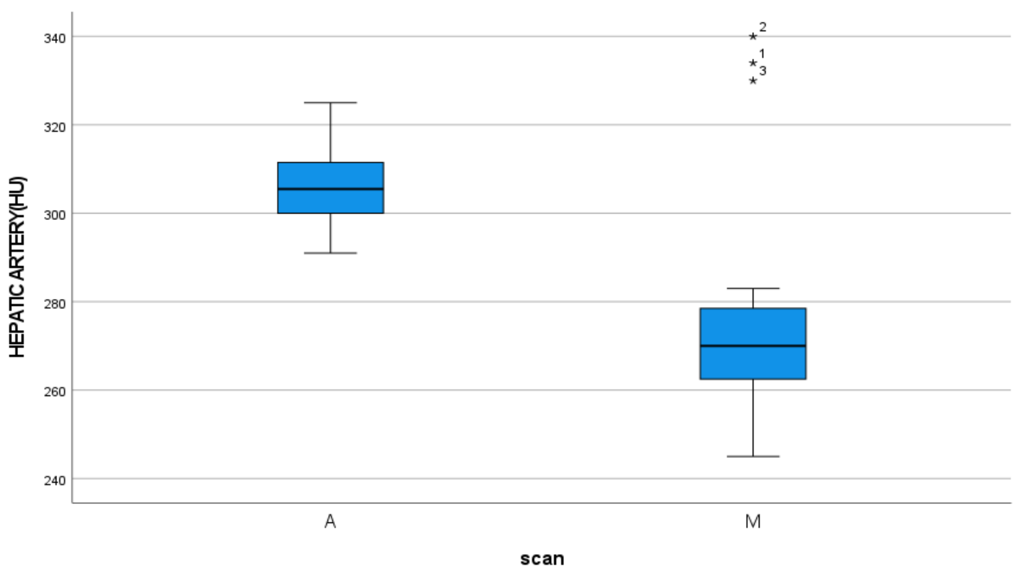

Figure 3A Hepatic artery enhancement in automatic bolus tracking and manual bolus tracking

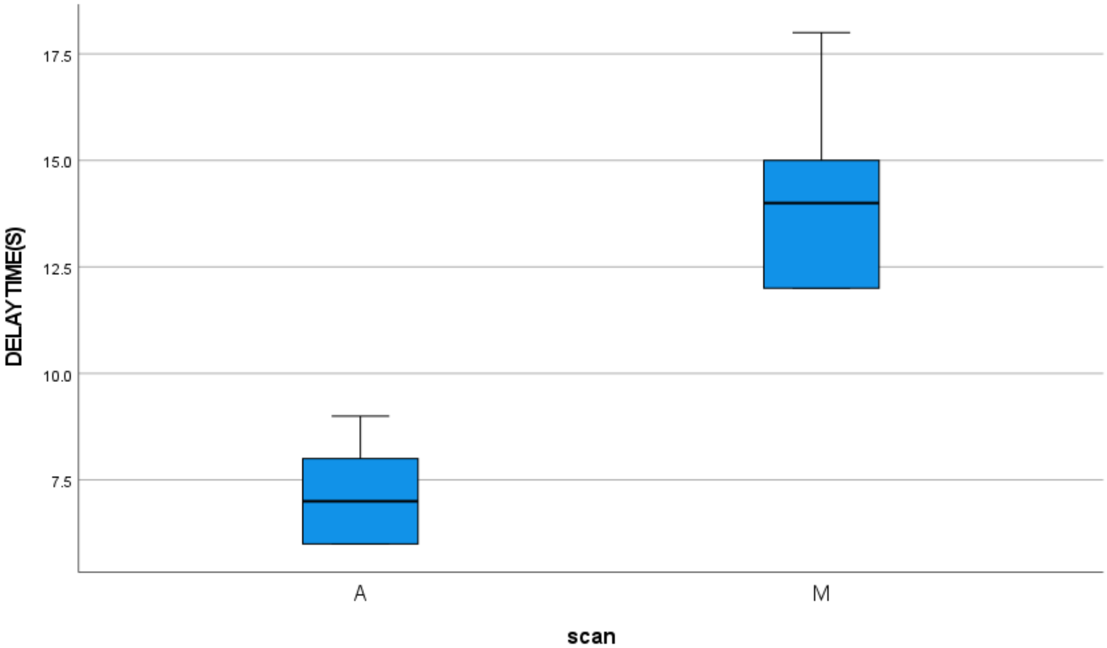

Figure 3B Delay timings difference in manual and automatic bolus tracking

In automatic bolus tracking group mean HU in thoracic aorta was found to be 371.6 with a minimum HU enhancement of 329 and maximum of 402. The mean HU in abdominal aorta was 363.75 with a minimum HU of 312HU and maximum HU of 391HU. The mean HU of hepatic artery was 306.42HU with a minimum and maximum mean HU being 291HU and 325HU respectively (Table 2, 3).

Table 3 Descriptive Statistics of manual bolus tracking

	N	Minimum	Maximum	Mean
Thoracic Aorta (HU)	36	310	373	346.69
Adominal Aorta (HU)	36	302	369	341.75
Hepatic Artery (HU)	36	245	340	272.86
Delay Time (S)	36	12	18	13.72

Table 3 shows that, in the automatic bolus tracking group mean HU in thoracic aorta was found to be 346.9HU with a minimum HU enhancement of 302HU and maximum of 373HU. The mean HU in the abdominal aorta was 341.75HU with a minimum HU of 302HU and maximum HU of 369HU. The mean HU of hepatic artery was 272.86HU with a minimum and maximum mean HU being 245HU and 340HU respectively.

4. DISCUSSION

With the introduction of intravenous contrast delivery, CT has continued to advance. A class of medications known as radiographic contrast media is used in CT scans to increase the visibility of internal organs and structures (Suetens, 2002). This method, which uses low-dose scans (approximately 50 mA), allows scans to begin, either manually or automatically, when the contrast enhancement reaches a specified threshold (Bae et al., 2008). A newly designed, automated hardware and software development, Smart Prep allows one to monitor contrast enhancement on scans during the early stages of contrast injection. The technique uses a series of low-radiation-dose monitoring scans that are swiftly rebuilt. Regions of interest (ROIs) of target structures (liver, aorta, portal vein) are displayed graphically and numerically, tracking their enhancement during the contrast administration (Bae et al., 2007).

In our study, we analyzed contrast enhancement based on HU in Thoracic Aorta, Abdominal Aorta and Hepatic Artery in automatic bolus tracking and manual bolus tracking. In our study, an independent sample t test (P value <0.001) was used and we found that a difference in mean HU in Thoracic Aorta (HU) and Abdominal Aorta (HU) between automatic bolus tracking and manual bolus tracking. We also found that there was a significant difference in Hepatic Artery (HU) and delay time of two groups (P value <0.001), using a Mann Whitney U Test. In our study, an increased HU enhancement was seen in automatic bolus tracking compared with manual bolus tracking.

A study which is similar to ours was conducted by Mehnert et al., (2001) showed a similar finding where automatic bolus tracking provides better HU enhancement. In our study found that delay timings was more in manual bolus tracking and optimized in automatic bolus tracking, in manual bolus tracking it was 13.72 seconds with a minimum 12 seconds and maximum 18 seconds and automatic bolus tracking was 7.17 seconds with a minimum and maximum being 6 seconds and 9 second respectively.

Sween et al., (2018) found automatic bolus tracking method where scan delays of 2 s are optimised for portal venous and hepatic venous phases and scan delay of 8 s is optimised for early arterial phase imaging when trigger threshold (100 HU) is met in the lower thoracic aorta. This phase was very useful for assessing the hepatic arterial tree. These observations support our study. Our study found, there was a significant difference between automatic bolus tracking and manual bolus tracking in thoracic aorta, abdominal aorta and hepatic aorta.

But Adibi and Shahbazi, (2014) found, in automatic bolus-tracking, contrast enhancement of the aorta, liver, and spleen was comparable between the two groups, with stronger contrast enhancement of the aorta and spleen at the portal phase. Our study revealed that, there was a significant different between two groups and Mehnert et al., (2001) performed a study on Automatic bolus tracking and they found that automatic bolus tracking was more efficient way to maximize the liver parenchymal contrast enhancement as same as our study and another study conducted by Frush et al., (1999) they done a study on children and found that, in children whose rate of contrast material infusion is variable, bolus tracking improves contrast enhancement, notably noticeably more during abdominal helical CT, hepatic enhancement same as our study.

In the present study shows automatic bolus tracking provided better enhancement and Stenzel et al., (2014) or coronary CT angiography, researchers compared bolus tracking with a predetermined trigger and manual fast start, and they came to the conclusion that both methods bolus tracking with a preset threshold and a manual fast start are appropriate. Their founding's were different from our study because our study shows significant differences between automatic bolus tracking and manual bolus tracking. Yoshida et al., (2020) also discovered that the contrast enhancement produced by the Bolus Tracking and Test Bolus approaches in CCTA was equal, and that there was no discernible difference in the distribution between the two groups.

Takumi et al., (2012) did a study on fifty individuals and obtained three separate hepatic CT examinations. The first and second tests were carried out using the bolus tracking approach. Using the first exam results, the third exam were executed with a using fixed scans delay method. On hepatic arterial phase differences in HU were examined in the abdominal organs and concluded that there was no HU difference on separate hepatic CT examinations. Also revealed that hepatic CT scans to follow up on hepato-cellular malignancy, a fixed scan delay approach utilizing previous bolus monitoring data is viable. In our study fixed time delay was not considered and compared only bolus tracking between automatic and manual techniques.

The present study concluded that automatic bolus tracking provides better enhancement than manual bolus tracking. A similar study that supports our results was done by Yu et al., (2022) in 104 patients using one of two bolus tracking approaches. They found an increased attenuation in abdominal images of arterial phase of automatic bolus tracking. Fukukura et al., (2010) carried out a study comparing fixed empirical scan time versus automated bolus tracking. The patient underwent a triphasic CT scan with both groups and was examined for enhancement. They came to the conclusion that automatic bolus tracking in MDCT gave greater enhancement. These data significantly backed up the findings of our investigation.

In our investigation, scan delays were optimized in automatic bolus tracking, Matsumoto et al., (2018) conducted a contradictory study on radiation dose reduction by modifying bolus tracking settings, and the patients were divided into four groups with varying delay timings. They discovered that delaying bolus start in bolus tracking or optimizing scan delay timings minimizes radiation dosage.

5. CONCLUSION

The HU enhancement will improve vessels visualization, and our study found that automatic bolus tracking had a higher HU enhancement than manual bolus tracking. In contrast enhanced computer tomography, adequate blood vessels enhancement in abdominal structures was critical, and our investigation found that automatic bolus tracking provided good enhancement. Delay timings were more in manual bolus tracking and optimized in automatic bolus tracking in our study. Optimized delay timings, on the other hand, reduced radiation exposure over the region of interest and overall effective dose reduction in the patient. When compared to manual bolus tracking, this study found that automatic bolus tracking was the most effective approach in triphasic CECT Abdomen.

Abbreviations

CT – Computed Tomography

CECT – Contrast Enhanced Computed Tomography

ROI – Region of Interest

MDCT – Multi Detector Computed Tomography

Acknowledgement

We thank the participants who all contributed samples to the study.

Ethical approval

The study was approved by Yenepoya Ethics Committee 2 (Ethical approval number: YEC2/1166/2022)

Informed consent

Written & Oral informed consent was obtained from all individual participants included in the study. Additional informed consent was obtained from all individual participants for whom identifying information is included in this manuscript.

Funding

This study has not received any external funding.

Conflict of interest

The authors declare that there is no conflict of interests.

Data and materials availability

All data sets collected during this study are available upon reasonable request from the corresponding author.

REFERENCES AND NOTES

1. Adibi A, Shahbazi A. Automatic bolus tracking versus fixed time-delay technique in biphasic multidetector computed tomography of the abdomen. Iran J Radiol 2014; 11(1):e4617. doi: 10.5812/iranjradiol.4617
2. Andreucci M, Solomon R, Tasanarong A. Side effects of radiographic contrast media: Pathogenesis, risk factors, and prevention. Biomed Res Int March 2014; 2014:741018. doi: 1 0.1155/2014/741018
3. Bae KT, Seeck BA, Hildebolt CF, Tao C, Zhu F, Kanematsu M, Woodad PK. Contrast enhancement in cardiovascular MDCT: Effect of body weight, height, body surface area, body mass index, and obesity. AJR Am J Roentgenol 2008; 1 90(3):777-84. doi: 10.2214/AJR.07.2765
4. Bae KT, Tao C, Gürel S, Hong C, Zhu F, Gebke TA, Milite M, Hildeolt CF. Effect of patient weight and scanning duration on contrast enhancement during pulmonary multidetector CT angiography. Radiology 2007; 242(2):582-9. doi: 10.1148/ radiol.2422052132
5. Bae KT. Intravenous contrast medium administration and scan timing at CT: Considerations and approaches. Radio logy 2010; 256:32-61. doi: 10.1148/radiol.10090908
6. Brink JA. Contrast optimization and scan timing for single and multidetector-row computed tomography. J Comput Assist Tomogr 2003; 27 Suppl 1:S3–8. doi: 10.1097/00004728-200305001-00003
7. Frush DP, Spencer EB, Donnelly LF, Zheng JY, De-Long DM, Bisset GS 3rd. Optimizing contrast-enhanced abdominal CT in infants and children using bolus tracking. AJR Am J Roentgenol 1999; 172(4):1007-13. doi: 10.2214/ajr. 172.4.10587137
8. Fukukura Y, Takumi K, Kamiyama T, Shindo T, Higashi R, Nakajo M. Pancreatic adenocarcinoma: A comparison of automatic bolus tracking and empirical scan delay. Abdom Imaging 2010; 35:548-55. doi: 10.1007/s00261-009-9560-5
9. Kopka L, Funke M, Fischer U, Vosshenrich R, Oestmann JW, Grabbe E. Parenchymal liver enhancement with bolus-triggered helical CT: preliminary clinical results. Radiology 1995; 195(1):282-4. doi: 10.1148/radiology.195.1.7892486
10. Matsumoto JKN, Assuncao-Jr AN, Dantas-Junior RN, Araujo-Filho JAB, Andrade SS, Nomura CH, Parga JR. Radiation dose reduction by adjusting bolus tracking parameters in a 320-detector row scanner. J Cardiovasc Comput Tomogr 2018; 12(4):312-315. doi: 10.1016/j.jcct.2018. 03.009
11. Mehnert F, Pereira PL, Trübenbach J, Kopp AF, Claussen CD. Automatic bolus tracking in monophasic spiral CT of

the liver: Liver-to-lesion conspicuity. Eur Radiol 2001; 11(4): 580-4. doi: 10.1007/s003300000637

12. Silverman PM, Brown B, Wray H, Fox SH, Cooper C, Roberts S, Zeman RK. Optimal contrast enhancement of the liver using helical (spiral) CT: Value of SmartPrep. AJR Am J Roentgenol 1995; 164(5):1169-71. doi: 10.2214/ajr.164.5.7717226
13. Silverman PM, Roberts S, Tefft MC, Brown B, Fox SH, Cooper C, Zeman RK. Helical CT of the liver: Clinical application of an automated computer technique, Smart Prep, for obtaining images with optimal contrast enhancement. AJR Am J Roentgenol 1995; 165(1):73-8. doi: 10.2214/ajr.165.1.7785637
14. Stenzel F, Rief M, Zimmermann E, Greupner J, Richter F, Dewey M. Contrast agent bolus tracking with a fixed threshold or a manual fast start for coronary CT angiography. Eur Radiol 2014; 24(6):1229-38. doi: 10.1007/s00330-014-3148-3
15. Suetens P. Fundamental of medical imaging. 2nd edition, Cambridge University. Cambridge University Press 2002.
16. Sween S, Samar C, Binu SM. Triple-phase MDCT of liver: Scan protocol modification to obtain optimal vascular and lesional contrast. Indian J Radiol Imaging 2018; 28:315-9. doi: 10.4103/ijri.IJRI_75_18
17. Takumi K, Fukukura Y, Shindo T, Kumagae Y, Tateyama A, Kamiyama T, Nakajo M. Feasibility of a fixed scan delay technique using a previous bolus tracking technique data for dynamic hepatic CT. Eur J Radiol 2012; 81(11):2996-3001. doi: 10.1016/j.ejrad.2012.02.022
18. Yoshida M, Matsumoto Y, Masuda T, Kikuhara Y, Kobayashi Y, Yoshiura T, Sato T. Comparison of Contrast Enhancement between Bolus-tracking and Test-bolus Methods on Coronary CT Angiography. Nihon Hoshasen Gijutsu Gakkai Zasshi 2020; 76(6):579-85. doi: 10.6009/jjrt.2020_JSRT_76.6.579
19. Yu J, Lin S, Lu H, Wang R, Liu J, Gutjahr R, Gao J. Optimize scan timing in abdominal multiphase CT: Bolus tracking with an individualized post-trigger delay. Eur J Radiol 2022; 148:110139. doi: 10.1016/j.ejrad.2021.110139