Kolta *et al. Egypt J Radiol Nucl Med (2023) 54:24*
https://doi.org/10.1186/s43055-023-00960-y

Egyptian Journal of Radiology and Nuclear Medicine

RESEARCH

Open Access

Comparison of maximum intensity projection and volume rendering on multidetector computed tomography in detecting pulmonary nodules

Marian Fayek Farid Kolta, Noura Mahmoud Higo, Inas Abdou Mohamed and Mohammed Raafat Abd El-Mageed*

Abstract

Background Lung cancer is the one of the most common types of cancer and considered as a leading cause of death from neoplasms. Almost all types of lung cancer develop from pulmonary nodules. The wide availability of the multi-detector computed tomography (MDCT) scanners makes the detection of pulmonary nodules much easier. Volume rendering (VR) and maximum intensity projection (MIP) techniques are the most commonly used post-processing techniques. The purpose of this research is to compare and contrast the two techniques in terms of the number and size of nodules.

Results In the current study, 32 patients with pulmonary nodules were included being referred from the chest department, with their age ranging from 27 to 71 years old. Nodules characteristics, such as number and size, were evaluated on both MIP and VR techniques. Paired comparison of number of pulmonary nodules less than 6 mm between MIP and VR showed statistically significant difference in 4, 7 and 10 mm slip thickness with *P*-value 0.003, 0.0001 and 0.0001, respectively. Paired comparison of number of pulmonary nodules more than 6 mm in size between MIP and VR showed no statistically significant difference in 4, 7 and 10 mm slip thickness with *P*-value > 0.05 each. Comparison of the pulmonary nodules numbers according to slip thickness showed that there was a statistically significant difference in the number of detected nodules, showing that 10 mm slip thickness is significantly higher compared to 4 mm and 7 mm with *P*-value 0.0001, 0.0001 for nodules < 6 mm, and 0.001 for the lung nodules > 6 mm in size.

Conclusions We can conclude the superiority of MIP over VR in detection of small sized nodules. MIP was easier to follow and showed high inter-reader agreement. The 10 mm MIP outperformed all other slab thicknesses for nodule detection less than 6 mm. There was no statistically significant difference between both techniques in terms of larger nodules measuring > 6 mm.

Keywords Pulmonary nodules, CT, MIP, VR

Background

Pulmonary nodules are common and usually incidental finding on chest computed tomography (CT) scan. They can be described as a well-demarcated, distinct and sharply marginated rounded opacity seen within

*Correspondence:
Mohammed Raafat Abd El-Mageed
mohammed.raafat@kasralainy.edu.eg
Faculty of Medicine - Cairo University, Cairo, Egypt

the pulmonary interstitium and its size should not exceed 30 mm in maximum transverse diameter [1].

Pulmonary nodules are being detected more frequently as chest CT scans become more widely available. However, pulmonary nodules have been linked to a wide range of diseases, including infectious, inflammatory, and neoplastic diseases. Rapid recognition of a pulmonary nodule, in addition to the distinguishing characters such as size, site, and density, must be documented in order to make a diagnosis [2].

Post-processing techniques were created to minimize the scanning time, reduce radiologist fatigue and increase efficiency. Several studies have founded the value of maximum MIP and VR techniques, in the detection of pulmonary nodules during routine reporting [2].

The MIP algorithm is useful in diagnoses because it can easily distinguish structures that are hyperdense in comparison to surrounding tissues. Detecting higher density voxels allows the radiologist to better understand the extension and morphology of some structures, such as nodules, calcifications, vessels, foreign bodies and surgical clips, and significantly minimizes the time required to analyze complex structures in multiple planes [3].

Volume rendering is a set of techniques for displaying a two-dimensional (2D) projection of a three-dimensional (3D) discretely sampled data set. These volume-rendered images can be sectioned and rotated in space to provide 3D insight into bone anatomy. 3D-rendered images add to surgical planning and teaching by providing additional information [4].

VR displays are useful as an additional diagnostic review of thoracic multidetector CT data sets to highlight small solid intrapulmonary nodules in patients examined for the diagnosis of lung metastases or bronchogenic carcinoma [5].

Previous research had found that the VR technique aided in the diagnosis and improved the detection of solid lung nodules. Furthermore, VR review with synchronizing side-by-side comparison has been found to be beneficial in CT follow-up for the growth evaluation of nodular ground-glass opacity, as it improves growth evaluation performance and reduces reading time [5].

The aim of this work is to determine which post-processing (maximum intensity projection and volume rendering) technique is the best for the detection of pulmonary nodules.

Methods

In this prospective study 32 patients were included, with their age ranging from 27 to 71 years old with median age of 58.5. The male-to-female proportions were 1:1.

Inclusion criteria

- Patients more than 18 years referred to the chest department of our institution for chest CT scan having pulmonary nodules.

Exclusion criteria

- Pregnant patient.
- CT chest with breathing artifacts, consolidation, pulmonary fibrosis and pneumoconiosis.

All cases were subjected to the following:

- Informed written consent was obtained from all patients prior to enrollment.
- Clinical examination with history taking, general and chest examination.
- Non enhanced CT.
- Post processing techniques were performed through GE work station (MIP and VR).

Protocol for CT chest study

Multidetector high-resolution CT protocols were applied with the patients in the dorsal decubitus position, during maximum inspiration, by using a 16-channel MDCT system. Contiguous axial slices of CT scans were obtained at 1.5 mm intervals, with 5 mm collimation, 130 Kvp, and an automatic tube modulation at 250 mA.

Data analysis

- Two radiologists reviewed the CT chest images along with the clinical data.
- The following characters of the pulmonary nodules were assessed:
- Nodule location: right or left lung.
- The size of the nodules
- The number of nodules.

Image analysis

Images were assessed using software imaging viewer (GE workstation). Data for different characteristics of pulmonary nodules were recorded. Each scan was interpreted by two radiologists independently, one having experience of **14** years and a trainee having experience of 2 years. The software was used to reconstruct at window level of −600 HU and window width of 1500 HU were set for analysis of lung nodules on MIP technique, while VR images were evaluated at −500 HU window level and width of −1500 HU. Nodules characteristics such as size and number were visually evaluated on both MIP and VR techniques. Both radiologists evaluated each scan six times using the following method: MIP and VR on slab thicknesses of 4, 7 and 10 mm respectively.

Statistical analysis

Statistical analysis was conducted using SPSS 22nd edition; qualitative were presented in frequency and percentages. Quantitative data were presented in median and range after normality testing, paired comparison between postprocessing tools was conducted using Wilcoxon paired rank test, and comparison between different slip thickness was conducted using Friedman test. Any P-value < 0.05 was considered significant.

Results

A total of 32 patients were included in our final analysis, they had a median age 58.5 (ranging from 27 to 71) years old, and male-to-female proportions were 1:1.

Maximum intensity projection (MIP)

The median and maximum numbers of the detected pulmonary are listed in Table 1, and it revealed the higher accuracy of the 10 mm slab thickness in detection of the pulmonary nodules less than 6 mm in size diameter compared to the other slab thicknesses. On the other side, there was no statistically significant difference between the all-slab thicknesses in detection of the pulmonary nodules larger than 6 mm in diameter.

Volume rendering (VR)

Regarding median and maximum number of the detected pulmonary nodules with VR tool, they are listed in Table 2. In this table, the superiority of 7 mm slab thickness in detection of the pulmonary nodules less than 6 mm in diameter is noted compared to the other slab thicknesses. For detection of the pulmonary nodules larger than 6 mm in diameter, the different slab thicknesses show the same accuracy.

Paired comparison

The paired comparison of the detected pulmonary nodules numbers between MIP and VR showed statistically significant difference in 4, 7 and 10 mm slip thickness with P-value 0.001, 0.0001 and 0.0001, respectively, as shown in Table 3.

Paired comparison of number of pulmonary nodules more than 6 mm in size between MIP and VR showed no statistically significant difference in 4, 7 and 10 mm slip thickness with P-value > 0.05 each as shown in Table 4.

Comparison of the detected pulmonary nodules numbers according to slip thickness (Table 5) showed that there was a statistically significant difference in the number of detected nodules, showing that 10 mm slip thickness is significantly higher compared to 4 mm and 7 mm with P-values 0.0001, 0.0001 for nodules < 6 mm, and 0.001 for nodules > 6 mm in size (as also shown in Figs. 1, 2 and 3).

Discussion

The accurate diagnosis of pulmonary nodules is a critical step in lung cancer screening. Despite its potential benefits, computer-aided detection (CAD) systems are not commonly employed by radiologists in clinical practice for pulmonary nodule diagnosis [6].

Early detection of a pulmonary nodule and its features such as size, density and site, must be documented in order to make a diagnosis. Post-processing techniques were created to minimize the scanning time, reduce

Table 1 Summary of pulmonary nodules count using MIP at various slab thicknesses by readers

MIP	Median	Maximum
Rt nodules less than 6 mm in size (4 mm slab thickness)	11.5	82
Rt nodules less than 6 mm in size (7 mm slab thickness)	14.5	102
Rt nodules less than 6 mm in size (10 mm slab thickness)	18.5	182
Rt nodules more than 6 mm in size (4 mm slab thickness)	2.0	30
Rt nodules more than 6 mm in size (7 mm slab thickness)	2.0	30
Rt nodules more than 6 mm in size (10 mm slab thickness)	2.0	30
Lt nodules less than 6 mm in size (4 mm slab thickness)	11.5	92
Lt nodules less than 6 mm in size (7 mm slab thickness)	15.5	113
Lt nodules less than 6 mm in size (10 mm slab thickness)	20.0	159
Lt nodules more than 6 mm in size (4 mm slab thickness)	1.5	49
Lt nodules more than 6 mm in size (7 mm slab thickness)	1.5	49
Lt nodules more than 6 mm in size (10 mm slab thickness)	1.5	49

Table 2 Summary of pulmonary nodules count using VR at various slab thicknesses by readers

VR	Median	Maximum
Rt nodules less than 6 mm in size (4 mm slab thickness)	8.0	55.0
Rt nodules less than 6 mm in size (7 mm slab thickness)	9.0	61.0
Rt nodules less than 6 mm in size (10 mm slab thickness)	8.5	41.0
Rt nodules more than 6 mm in size (4 mm slab thickness)	2.0	43.0
Rt nodules more than 6 mm in size (7 mm slab thickness)	2.0	43.0
Rt nodules more than 6 mm in size (10 mm slab thickness)	2.0	43.0
Lt nodules less than 6 mm in size (4 mm slab thickness)	8.0	75.0
Lt nodules less than 6 mm in size (7 mm slab thickness)	11.0	82.0
Lt nodules less than 6 mm in size (10 mm slab thickness)	9.5	45.0
Lt nodules more than 6 mm in size (4 mm slab thickness)	2.5	35.0
Lt nodules more than 6 mm in size (7 mm slab thickness)	2.0	35.0
Lt nodules more than 6 mm in size (10 mm slab thickness)	2.5	35.0

Table 3 Paired comparison of nodule count with respect to MIP and VR at various slab thicknesses by readers

	MIP		VR		*P* value
	Media	Min–Max	Median	Min–Max	
4 mm	14.8	2.5–94	11.0	1.5–79.5	0.001
7 mm	17.3	3–114.5	12.8	2–87	0.0001
10 mm	19.8	3.5–177.5	10.8	2.5–59.5	0.0001

Table 4 Paired comparison of nodule more than 6 mm count with respect to MIP and VR at various slab thicknesses by readers

	MIP		VR		*P* value
	Median	Min–Max	Median	Min–Max	
4 mm	1.5	0–35.5	2	0–39	0.618
7 mm	1.5	0–35.5	2	0–39	0.601
10 mm	1.5	0–35.5	2	0–39	0.618

radiologist fatigue and increase efficiency. Several studies have found the value of maximum MIP and VR techniques, in the detection of pulmonary nodules during routine reporting [2].

In the current study we conducted a prospective study including 32 patients to assess the difference of the detected pulmonary nodules numbers between VR and MIP post-processing systems.

In the current study, paired comparison of the detected pulmonary nodules numbers between MIP and VR revealed higher detection of the MIP technique for the pulmonary nodules and showed statistically significant difference in 4, 7 and 10 mm slip thickness with *P*-value 0.001, 0.0001 and 0.0001, respectively.

Paired comparison of number of pulmonary nodules less than 6 mm between MIP and VR showed statistically significant difference in 4, 7 and 10 mm slip thickness with *P*-value 0.003, 0.0001, and 0.0001, respectively, with higher number detected by MIP versus VR. However, there was no statistically significant difference in 4, 7 and 10 mm slip thickness with *P*-value > 0.05 for each thickness for nodules more than 6 mm.

Our data also showed that comparison of the detected pulmonary nodules numbers according to slip thickness showed that there was a statistically significant difference in the number of detected nodules, showing that 10 mm slip thickness is significantly higher compared to 4 mm and 7 mm with *P*-values 0.0001, 0.0001 for nodules < 6 mm, and 0.001 for nodules > 6 mm in size.

Table 5 Comparison of difference in number of pulmonary nodules according to slip thickness

Slip thickness	Nodules		< 6 mm nodules		> 6 mm nodules	
	Median	Min–Max	Median	Min–Max	Median	Min–Max
4 mm	3	0–41	3	0–27	4.5	0–46
7 mm	5	0–57	4	0–48	6	0–63
10 mm	8.5	0–122	12	0–154	8.5	0–128
P value	0.0001		0.0001		0.001	

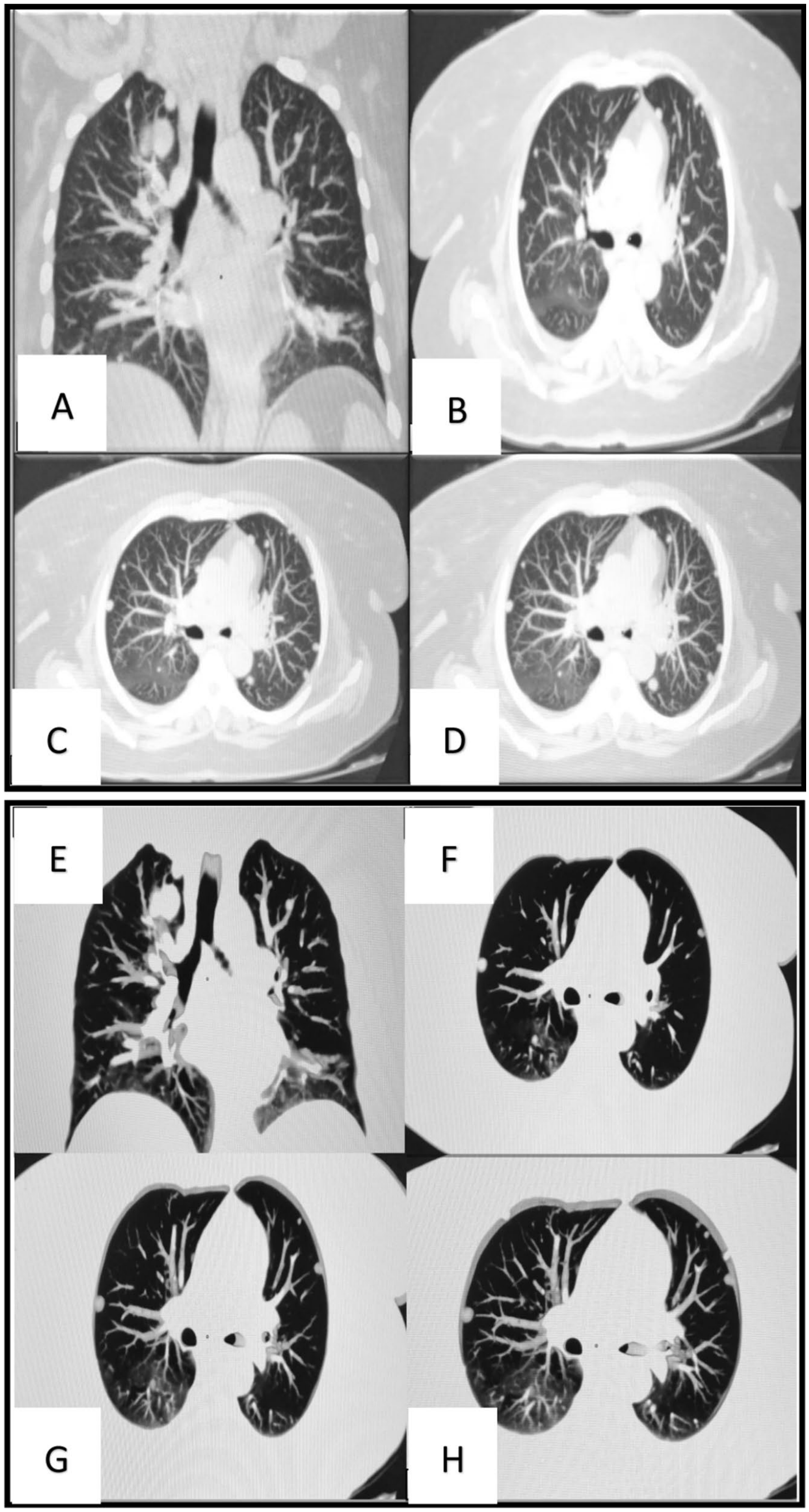

Fig. 1 A 59-year-old female patient with history of anaplastic thyroid carcinoma. MIP coronal (**A**) and axial sections at 4 mm (**B**), 7 mm (**C**) and 10 mm (**D**) slab thickness. VR coronal (**E**) and axial sections at 4 mm (**F**), 7 mm (**G**) and 10 mm (**H**) slab thickness. A number of the nodules detected by the MIP at 4 mm, 7 mm and 10 mm are 78, 126 and 136 nodules, respectively, compared to 70, 80 and 58 pulmonary nodules detected by the VR technique at 4 mm, 7 mm and 10 mm, respectively. The number of the pulmonary nodules detected by each technique by each slab thickness is listed at Table 6

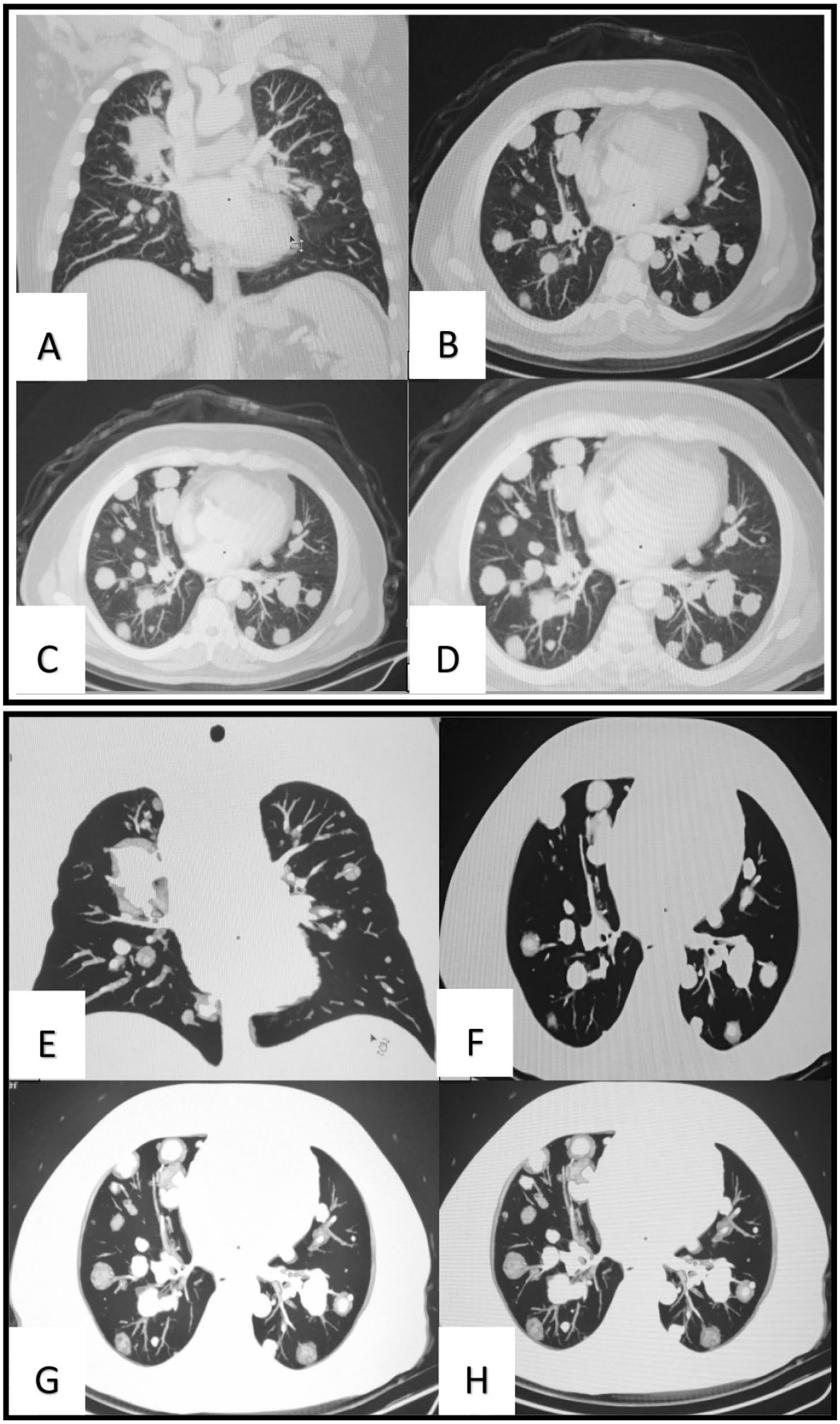

Fig. 2 A 64-year-old male patient presented with colon cancer underwent surgery and chemotherapy. MIP coronal (**A**) and axial section at 4 mm (**B**), 7 mm (**C**) and 10 mm (**D**) slab thickness. VR coronal (**E**) and axial sections at 4 mm (**F**), 7 mm (**G**) and 10 mm (**H**) slab thickness. A number of the nodules detected by the MIP at 4 mm, 7 mm and 10 mm are 159, 170 and 176 nodules, respectively, compared to 150, 165 and 127 pulmonary nodules detected by the VR technique at 4 mm, 7 mm and 10 mm, respectively. The number of the pulmonary nodules detected by each technique by each slab thickness is listed at Table 7

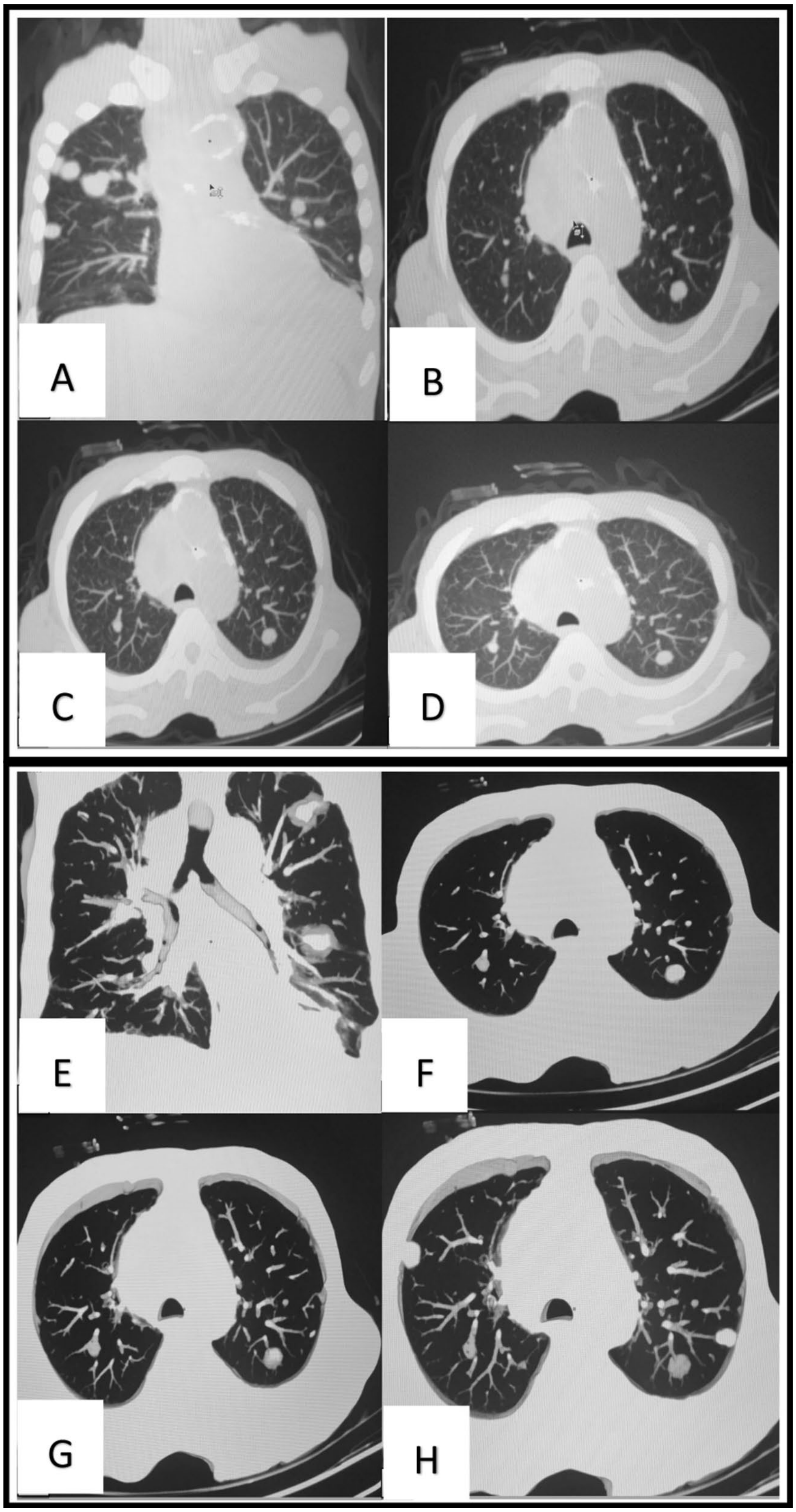

Fig. 3 A 70-year-old male patient presented with cancer urinary bladder. MIP coronal (**A**) and axial section at 4 mm (**B**), 7 mm (**C**) and 10 mm (**D**) slab thickness. VR coronal (**E**) and axial sections at 4 mm (**F**), 7 mm (**G**) and 10 mm (**H**) slab thickness. A number of the nodules detected by the MIP at 4 mm, 7 mm and 10 mm are 54, 59 and 65 nodules, respectively, compared to 48, 43 and 36 pulmonary nodules detected by the VR technique at 4 mm, 7 mm and 10 mm, respectively. The number of the pulmonary nodules detected by each technique by each slab thickness is listed at Table 8

Table 6 Size of pulmonary nodules at mentioned slab thicknesses

Slap thickness	MIP		VR	
	< 6 mm	> 6 mm	< 6 mm	> 6 mm
4 mm	41	37	41	29
7 mm	89	37	51	29
10 mm	99	37	29	29

Table 7 Size of pulmonary nodules at mentioned slab thicknesses

Slap thickness	MIP		VR	
	< 6 mm	> 6 mm	< 6 mm	> 6 mm
4 mm	81	78	72	78
7 mm	92	78	87	78
10 mm	98	78	49	78

Table 8 Size of pulmonary nodules at mentioned slab thicknesses

Slab thickness	MIP		VR	
	< 6 mm	> 6 mm	< 6 mm	> 6 mm
4 mm	30	24	24	24
7 mm	28	24	19	24
10 mm	41	24	12	24

Our findings agreed with Sharma et al. [7], who found that there was statistical significance between MIP and VR of 4 mm slab thickness in nodule detection with *P* value of 0.013 with MIP detection rate exceeding VR. However, it disagreed in their result which revealed that there was no statistical difference between the two techniques with 7 and 11 mm slab thickness with *P* value of > 0.05 and between radiologists also there was good agreement.

Sharma et al. [7] also showed that total nodule count in MIP and VR was statistically significant different between MIP and VR for nodules less than 3 mm and 4–6 mm size with a *P*-value of 0.041 and 0.047, respectively. However, there was no significant difference between MIP and VR for 7–10 mm size of nodules (*P*-value 0.144).

These findings were consistent with the current results which demonstrated that significant difference was only reported in smaller pulmonary nodules < 6 mm, while there was no significant difference in relatively larger nodules > 6 mm.

Kawel et al. [8], found that MIP with an 8 mm slab thickness had much higher sensitivity for nodule detection in chest CT than all other investigated techniques: 5 mm MIP, 11 mm MIP, 5 mm VR, 8 mm VR, and 11 mm VR. As well, MIP was found to be substantially superior to VR for detecting nodules less than 7 mm in the current investigation; however, there was no significant difference between MIP and VR for detecting nodules larger than 7 mm. These findings are in line with the findings detected in the current study.

Our results also matched with those reported by a study conducted by Naeem et al. [2], who stated that MIP post processing technique detected more pulmonary nodules using a slab thickness 4 mm identified 2028, with the 7 mm slap thickness identified 2423, while 10 mm slap thickness identified 2499 pulmonary nodules as compared to VR technique using slab thickness 4 mm which identified 1693, with 7 mm identified 2081 and 10 mm identified 2169 pulmonary nodules, respectively.

Our study was also in agreement with study carried out by Khan et al. [9], who included a total of 445 nodules detected using MIP technique, with 356 (80%) being seen by VR and the remaining 89 (20%) not being diagnosed. They concluded that the maximum intensity projection imaging technique is superior to volume rendering for diagnosing tiny pulmonary nodules.

In the current study, we faced the limitation of small sample size.

Conclusions

We can conclude the superiority of MIP over VR in detection of small sized nodule. The 10 mm MIP outperformed the other slab thicknesses for nodule detection less than 6 mm. There was no statistically significant difference between both techniques in terms of large nodules > 6 mm and slab thickness 10 mm.

Abbreviations

MDCT	Multi-detector computed tomography
MIP	Maximum intensity projection
VR	Volume rendering (VR)
2D	Two-dimensional
3D	Three-dimensional
CAD	Computer-aided detection

Acknowledgements

The authors would like to thank all the personnel contributed in this study.

Author contributions

MF shared in study conception and design, processing CT findings and shared in writing and correcting the manuscript and revision. NM shared in study conception and design, processing CT findings and shared in writing and correcting the manuscript and revision. IA shared in study conception and design, writing and correcting the manuscript and revision. MR shared in study conception and design, acquisition of data, analysis and interpretation of data and drafting of manuscript. All authors read and approved the final manuscript.

Funding

This study had no funding from any resource.

Availability of data and materials
The datasets used and/or analyzed during the study are available upon reasonable request.

Declarations

Ethics approval and consent to participate
No individual data included in the study. This study was approved by the Research Ethics Committee of the Faculty of Medicine at Cairo University Kasr El-Aini in Egypt in August 2020; reference number MS-506-2021. All patients included in this study gave verbal informed consent to participate in this research. If the patient was unconscious at the time of the study, written informed consent for their participation was given by their legal guardian.

Consent for publication
All patients included in this study gave written informed consent to publish the data contained within this study. If the patient was unconscious when consent for publication was requested, written informed consent for the publication was given by their legal guardian.

Competing interests
The authors declare that they have no competing interests.

Received: 4 November 2022 Accepted: 5 January 2023
Published online: 01 February 2023

References

1. Au-Yong ITH, Hamilton W, Rawlinson J, Baldwin DR (2020) Pulmonary nodules. BMJ m3673. https://doi.org/10.1136/bmj.m3673
2. Naeem MQ, Darira J, Ahmed MS, Hamid K, Ali M, Shazlee MK (2021) Comparison of maximum intensity projection and volume rendering in detecting pulmonary nodules on multidetector computed tomography. Cureus 13(3):e14025–e14025
3. Perandini S, Faccioli N, Zaccarella A, Re T, Mucelli RP (2010) The diagnostic contribution of CT volumetric rendering techniques in routine practice. Indian J. Radiol. Imaging 20(02):92–97
4. Katkar RA, Taft RM, Grant GT (2018) 3D volume rendering and 3D printing (additive manufacturing). Dent Clin North Am 62(3):120–132
5. Naeem MQ, Darira J, Ahmed MS, Hamid K, Ali M, Shazlee MK (2021) Comparison of maximum intensity projection and volume rendering in detecting pulmonary nodules on multidetector computed tomography. Cureus. https://doi.org/10.7759/cureus.14025
6. Zheng S, Guo J, Cui X, Veldhuis RN, Oudkerk M, Van Ooijen PM (2019) Automatic pulmonary nodule detection in CT scans using convolutional neural networks based on maximum intensity projection. IEEE Trans Med Imaging 39(3):797–805
7. Sharma D, Yadav S, Prakshini K, Paruthikunnan S, Dhkar W (2016) Comparison of MIP and VR with average at various slab thickness in MDCT for detecting pulmonary nodules. Online J Health Allied Sci 15:6
8. Kawel N, Seifert B, Luetolf M, Boehm T (2009) Effect of slab thickness on the CT detection of pulmonary nodules: use of sliding thin-slab maximum intensity projection and volume rendering. Am J Roentgenol 192(5):1324–1329
9. Khan F, Anjum A, Nasim R (2019) Examine the benefits and usefulness of computed tomography for diagnosis small pulmonary nodules by using maximum intensity projection images compare to volume rendering. Pak J Med Health Sci 13(4):1320–1321

Publisher's Note