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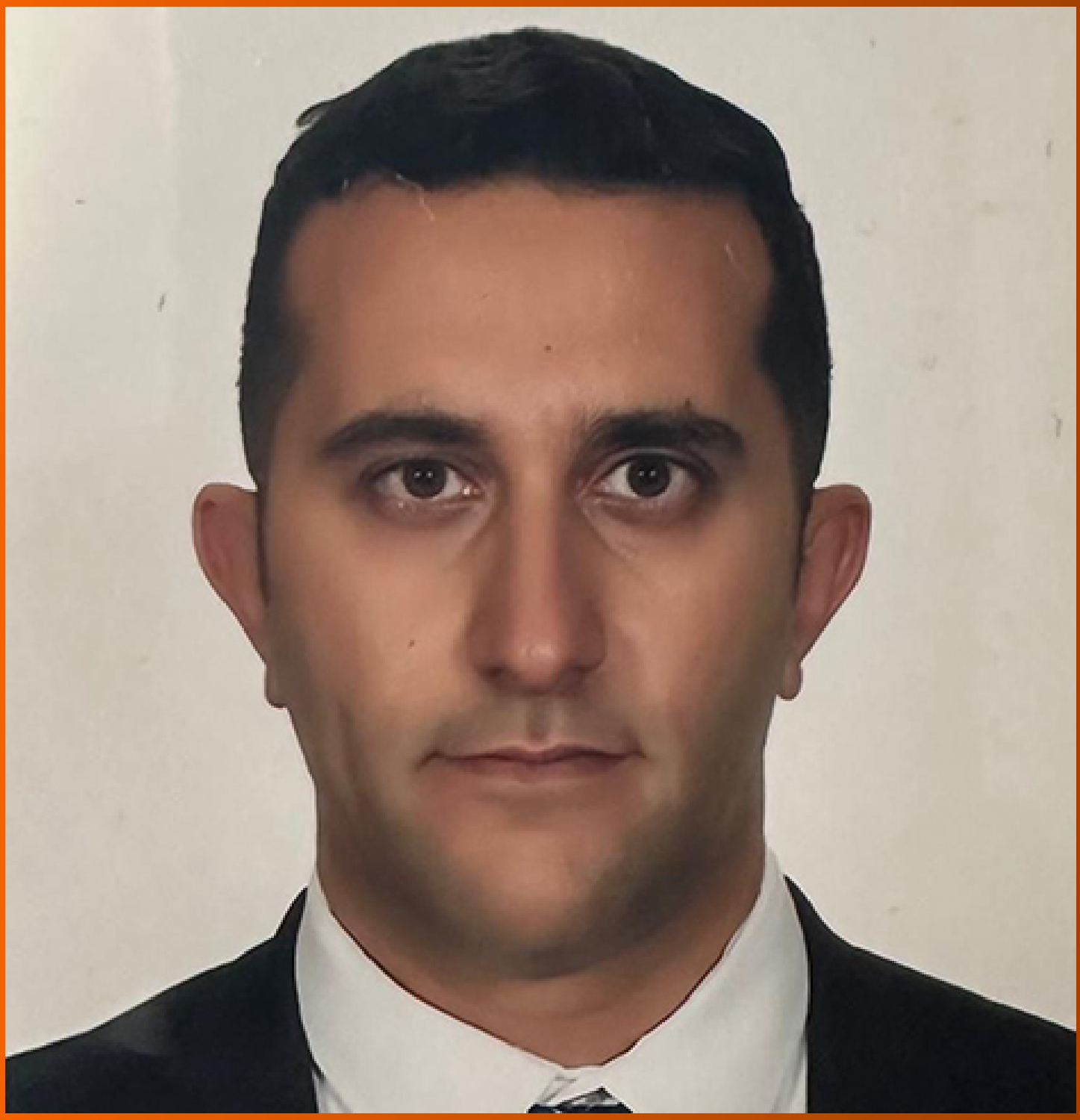

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The primary aim of the *World Journal of Clinical Pediatrics* (*WJCP*, *World J Clin Pediatr*) is to provide scholars and readers from various fields of pediatrics with a platform to publish high-quality clinical research articles and communicate their research findings online.

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ORIGINAL ARTICLE

Retrospective Study

Radiation dose analysis of computed tomography coronary angiography in Children with Kawasaki disease

Mahesh Chandra Bhatt, Manphool Singhal, Rakesh Kumar Pilania, Subhash Chand Bansal, Niranjan Khandelwal, Pankaj Gupta, Surjit Singh

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Abstract

BACKGROUND

There is evolving role of computed tomography coronary angiography (CTCA) in non-invasive evaluation of coronary artery abnormalities in children with Kawasaki disease (KD). Despite this, there is lack of data on radiation dose in this group of children undergoing CTCA.

AIM

To audit the radiation dose of CTCA in children with KD.

METHODS

Study (December 2013-February 2018) was performed on dual source CT scanner using adaptive prospective electrocardiography-triggering. The dose length product (DLP in milligray-centimeters-mGy.cm) was recorded. Effective radiation dose (millisieverts-mSv) was calculated by applying appropriate age adjusted conversion factors as per recommendations of International Commission on Radiological Protection. Radiation dose was compared across the groups (0-1, 1-5, 5-10, and > 10 years).

RESULTS

Eighty-five children (71 boys, 14 girls) with KD underwent CTCA. The median age was 5 years (range, 2 mo-11 years). Median DLP and effective dose was 21 mGy.cm, interquartile ranges (IQR) = 15 (13, 28) and 0.83 mSv, IQR = 0.33 (0.68, 1.01) respectively. Mean DLP increased significantly across the age groups. Mean effective dose in infants (0.63 mSv) was significantly lower than the other age

groups (1-5 years 0.85 mSv, 5-10 years 1.04 mSv, and > 10 years 1.38 mSv) ($P < 0.05$). There was no significant difference in the effective dose between the other groups of children. All the CTCA studies were of diagnostic quality. No child required a repeat examination.

CONCLUSION

CTCA is feasible with submillisievert radiation dose in most children with KD. Thus, CTCA has the potential to be an important adjunctive imaging modality in children with KD.

Key Words: Computed tomography coronary angiography; Coronary artery abnormalities; Dual source computed tomography; Kawasaki disease; Radiation exposure

Core Tip: Dual source computed tomography (CT) scanners by virtue of high temporal resolution, faster gantry rotation, electrocardiography triggered tube current modulation, large area coverage, body adaptive automatic selection of tube current modulation and iterative reconstruction algorithm have largely addressed the issue of high radiation exposure when subjecting children with Kawasaki disease (KD) to CT coronary angiography. It is now possible to evaluate these patients using submilliseivert radiation exposure. This is a significant advance in management of KD.

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INTRODUCTION

Kawasaki disease (KD) is a common childhood medium vessel vasculitis with special propensity for coronary arteries. It typically affects children below 5, however, older children and young adults can also be affected. Diagnosis of KD is based on constellation of clinical features, and there are no pathognomonic laboratory tests. Children with KD fluffing the epidemiological case definition are known as complete KD. Incomplete and atypical forms of disease can constitute up to 50% of patients with KD[1-4]. Coronary artery abnormalities (CAAs) represent the major contributors to both acute as well as long term morbidity and mortality related to KD[4-8]. Timely treatment of KD reduces the CAAs incidence from 25% to < 5%. Timely and precise evaluation of CAAs is important for management of patients with KD[4]. 2D-echocardiography (ECHO) has hitherto been the first line imaging modality for evaluation of CAAs. However, it has some inherent limitations. These include operator dependency, poor acoustic window and lack of visualization of middle and distal segments of coronary arteries[6]. Further, it is difficult to visualize the coronaries in older children who have thick chest walls[9,10]. Catheter angiography (CA) is the gold standard imaging modality but has the disadvantages of being invasive and is associated with high radiation exposure[11-13].

Recently, multi-detector CT (MDCT) and dual source CT (DSCT) platforms have allowed imaging of coronary arteries at any heart rate with attempts at radiation optimization[14-18], which otherwise is a serious concern in children[19,20]. There are limited studies that to with small sample size on radiation dose in children with KD undergoing CTCA on DSCT (Table 1). Radiation dose in these studies was either more or comparable to our study. This study enumerates various methods to optimize the radiation exposure on CTCA in children with KD, an audit of the radiation dose and show that radiation exposure can be reduced to 1mSv or less in majority of children.

MATERIALS AND METHODS

Study design

Review of records was carried out during the period December 2013-February 2018. The manuscript has been approved by Departmental Publication Review Board (RDG/EC/Pub/27 dated July 03, 2020). Written informed consent was obtained from parents prior to CTCA.

Patient population

Children with KD who underwent CTCA were either at presentation or on regular follow-up with CAAs on ECHO were included in the analysis. As per International Commission on Radiological Protection-103 (ICRP 103) recommendations, children were grouped as per age into infants (< 1 year), 1-5 years, 5-10 years, > 10 years. System generated radiation exposure dose length product (DLP in milligray-centimeters-mGy.cm) was recorded and effective radiation dose (millisieverts-mSv) was calculated by applying age adjusted conversion factors recommended by ICRP 103[21] and analysis of

Table 1 Comparison of effective radiation dose on dual source computed tomography coronary angiography platforms in patients with Kawasaki disease

Ref.	Country	Number of cases	Platform	ECG triggering	Age	Radiation dose	Remarks
Duan *et al*[27], 2012	China	19	DSCT	Prospective	Range: 3 mo-5 yr	ED (mean ± SD): 0.36 ± 0.06 mSv	
Kim and Goo [28], 2013	Korea	51	DSCT: (1) 64-Slice: *n* = 49; and (2) 128-Slice: *n* = 2	Retrospective in most of the patients	Mean (range): 13.2 (1-24) yr	ED (mean ± SD): (1) 64-Slice: 2.6 ± 2.7 mSv; and (2) 128-Slice: 2.1 ± 0.6 mSv	ED was only 0.6 ± 0.5 mSV in 5 children < 2 yr of age, who underwent prospective ECG-triggering
Ghoshhajra *et al*[29], 2014	United States	52	DSCT: (1) 64-Slice: *n* = 16; and (2) 128-Slice: *n* = 36	Prospective	Range: 0-18 yr	Median (IQR) ED: (1) 64-Slice: 2.9 (0.9-4.1) mSV; and (2) 128-Slice: 1.0 (0.6-2.0) mSV	ED significantly reduced compared to 16 and 64-Slice Scanner platforms
Kantarcı *et al* [30], 2019	Turkey	17	128-Slice DSCT	Details NA	Mean (range): 3 yr (2 mo-11.3 yr)	ED range: 1.2-4.3 mGy depending on the patient's body weight	
van Stijn *et al* [26], 2020	Netherlands	70	DSCT: (1) 2 × 192-Slice: *n* = 56; and (2) Other CT scanners (64/128/320-Slice): *n* = 14	Prospective	Median (range): 15.1 (0.5-59.5) yr	Median (range) ED: (1) 2 × 192-Slice: 1.5 (0.3-9.4) mSv; and (2) Other CT scanner: 3.8 (1.7-20.0) mSv	This is the only study on 3rd generation DSCT platform
Borhanuddin *et al*[31], 2022	Malaysia	52	64-slice DSCT	Retrospective	Median (range): 5 (1-18) yr	Median (range) ED: 0.81 (0.4-5.8)	
Present study, Chandigarh	India	85	128-Slice DSCT	Prospective	Median (range): 5 yr (2 mo-11 yr)	Median (IQR) ED: 0.83 (0.68-1.01)	Largest study on 128-Slice platform which provides data that CTCA can be performed in sub-millisievert doses

CTCA: Computed tomography coronary angiography; DSCT: Dual source computed tomography; ED: Effective radiation dose; IQR: Interquartile range.

radiation exposure across groups was done (Table 2).

CTCA technique

CTCA was carried out on a second generation DSCT 128-slice scanner (Somatom Definition Flash, Siemens, Erlangen, Germany) using non-ionic contrast (Omnipaque 350, GE Healthcare, Ireland) with the following parameters: Temporal resolution- 75 milliseconds, gantry rotation time-0.28 s, slice thickness-0.6 mm. The scan was conducted in a craniocaudal direction from floor of carina to the diaphragm (till base of heart). CTCA was carried out with adaptive prospective electrocardiography (ECG) triggered sequence (CorAdSeq) tube current modulation to minimize radiation exposures without compromising image quality. With this technique the CT X-ray tube is switched on at the predefined range of R-R interval of ECG (in our study 30%-80% R-R interval) and provides images in systolic and diastolic phases.

Scanning parameters were customized to ensure minimal radiation exposure. Volume CT dose index (CTDIvol) was taken as adjusted by the CT scanner according to body-size adapted protocols-CARE Dose4D (Siemens, Erlangen, Germany). With this tube current-time product (mA.s) is automatically calculated for optimal automatic exposure depending on body weight and cross-sectional area. Automatic CARE kV was switched off and adjusted to 80 kilovolt (kVp) in all children. These modifications, along with CARE-Dose 4D tube current modulation, enabled us to further reduce the effective radiation dose. Lowest kVp and mAs values ensured optimal image quality with minimum possible radiation exposure. The current-time product ranged between 32-154 mA.s.

Statistical analysis

Parameters showing normal distribution were depicted as mean and standard deviation, while variables with skewed distribution were expressed as median and interquartile ranges (IQR). A P value of < 0.05 was regarded as significant. Statistical analysis was accomplished using SPSS statistical software version 20.0 (SPSS Inc., Chicago, IL, United States).

RESULTS

Demographic characteristics

CTCA of 85 patients [71 (84%) boys; 14 (16%) girls] with KD were acquired. Median age of our cohort was 5 years [IQR: 5

Table 2 Conversion factors for chest in different age groups at 80 kV according to recent International Commission on Radiological Protection recommendations (20)

S.No.	Age group	Tube voltage (kV)	Conversion factor
1	< 1 yr	80	0.0823
2	> 1 - < 5 yr	80	0.0525
3	> 5 - < 10 yr	80	0.0344
4	≥ 10 yr	80	0.0248

(7, 2)]; range: 2 mo-11 years. As per ICRP 103 recommendations, children were grouped as per age into infants (< 1 year) (n-10; 12%), 1-5 years (n-29; 34%), 5-10 years (n-38; 45%), > 10 years (n-8; 9%).

Radiation dose

The median DLP and effective dose of all 85 patients in our study were 21.0 mGy.cm, IQR = 15 (13, 28) and 0.83 mSv, IQR = 0.33(0.68, 1.01), respectively. Details of DLP and effective CT radiation dose for children in study group are given in Table 3.

The mean DLP in infants, 1-5 years, 5-10 years, and > 10 years was 9.19, 18.82, 31.76, and 55.67 mGy.cm, respectively. The mean effective dose in infants, 1-5 years, 5-10 years, and > 10 years was 0.63, 0.83, 1.04, and 1.38 mSv. The DLP showed significant increase with increasing age. The difference in the DLP was statistically significant across all age groups (P value for infants *vs* 1-5 years, 1-5 years *vs* 5-10 years, and 5-10 years > 10 years; < 0.001, < 0.001, and 0.01, respectively. The mean effective dose in infants (0.63 mSv) was significantly lower than the other age groups (1-5 years 0.85 mSv, 5-10 years 1.04 mSv, and > 10 years 1.38 mSv) (P < 0.05). There was no significant difference in the effective dose among children in the other groups.

All the CTCA studies were of diagnostic quality. No child required a repeat examination.

DISCUSSION

We performed CTCA on 128-DSCT scanner with radiation optimized protocols (CorAdSeq tube current modulation, body-size adapted protocols and reduced tube kilovoltage settings at 80 kVp) to minimize radiation exposures. In total 85 children with median age of 5 years [IQR: 5 (7, 2)]; (range: 2 mo-11years) were scanned. The mean effective radiation dose was 0.83 mSv with radiation exposure significantly lower in infants (0.63 mSv) as compared to other age groups. CTCA can visualize CAAs along the entire course of coronary arteries[6].

KD is a medium vessels vasculitis with special predilection for involvement of coronary arteries[1-4]. ECHO has hitherto been considered the imaging modality of choice for diagnosis and follow-up of CAAs in patients with KD, but with many limitations related to comprehensive evaluation of coronary arteries. CA is the gold standard, but is associated with inordinate radiation exposure, is invasive and cannot be repeated often for follow-up. Moreover, mural abnormalities cannot be depicted on CA[9,22].

With the advent of new high MDCT and DSCT scanners, imaging of coronary arteries is possible. However, until recently the risk of high radiation exposure had precluded the use of CTCA in children with KD. This was probably the limiting factor that prevented its application in pediatrics when cardiac CT on single source 64-slice was made possible. CTCA with single source 64-Slice CT is associated with radiation exposure as high as 3.0-5.7 mSv[23]. Moreover, this technique resulted in sub-optimal image quality due to inability to acquire images at high heart rates in children. Though there are no criteria to define limits of radiation dose in children, authors are of the opinion that this is clearly unacceptable in children and every possible method should be used to reduce radiation exposure in children as per ALARA (as low as reasonably achievable) principle[24]. Higher slice and dual source CT scanners with improvised technologies have emerged as promising platforms for CTCA with possibility for radiation optimization providing a promising imaging modality for assessment of CAAs of KD vis-a-vis CA.

Various dose-saving strategies that can be adopted during CTCA on DSCT are body size-adapted protocols including low tube voltage techniques, ECG-controlled and attenuation-based tube current modulations, and prospectively ECG-triggered scanning[14-18]. Lowering the KVp values (to 80) results in a significant dose reduction with acceptable image quality[25]. We have used adaptive prospective ECG-triggered sequence with tube current modulation, lower tube voltage (80 kVp) and optimized system calculated tube current using CARE-Dose 4D for radiation reduction. Iterative reconstruction algorithm that was used in our protocol in addition provides excellent quality images even at low exposure.

van Stijn *et al*[26] recently published a study on coronary artery assessment in patients with KD using 3rd generation DSCT platform (2 × 192-Slice CT scanner) on 70 children. The authors achieved a radiation exposure of 1.5 mSv (range 0.3-9.4 mSv)[26]. The radiation dose in our cohort was lower. Median effective dose of radiation 0.83 mSv (0.68-1.01) in our study is amongst the lowest achieved so far on DSCT platform using 128-Slice CT scanner. Further, cohort sizes in the previously published studies have been much smaller than ours[26-31] (Table 1). Having achieved such low radiation exposures and given the fidelity of images acquired on these platforms, it may not be long before CTCA on a DSCT platform becomes the imaging modality of choice for detailed evaluation of CAAs in children with KD.

Table 3 Effective computed tomography radiation exposure according to age in adaptive prospective electrocardiography-triggered sequence computed tomography coronary angiography on 128-dual source computed tomography platform

S.No.	Age group	Mean DLP (mGy.cm)	Mean effective radiation dose (mSv)
1	0-1 yr (n = 10)	9.19 ± 2.21	0.63 ± 0.16
2	1-5 yr (n = 29)	18.82 ± 8.48	0.85 ± 0.41
3	5-10 yr (n = 38)	31.79 ± 14.14	1.04 ± 0.37
4	> 10 yr (n = 8)	55.67 ± 19.39	1.38 ± 0.48

DLP: Dose length product; mSV: Millisievert.

We recognize several limitations to our study. The data in the current study comes from a single center and more such studies are required for further validation of our results. Further, there were fewer children in individual age groups. The cumulative impact of radiation dose in children who may require follow up CTCA is not known. Though, all the scans were of diagnostic quality, it is desirable to assess image quality along with radiation dose. However, our study was not tailored to assess the image quality.

CONCLUSION

In conclusion, DSCT scanners by virtue of high temporal resolution, faster gantry rotation, ECG triggered tube current modulation, large field of view, body adaptive automatic selection of tube current modulation and iterative reconstruction algorithm have largely addressed the issue of high radiation exposure when subjecting children with KD to CTCA. It is now possible to evaluate these patients using submilliseivert radiation exposure. This is a significant advance in management of KD.

ARTICLE HIGHLIGHTS

Research background

There is evolving role of computed tomography coronary angiography (CTCA) in non-invasive evaluation of coronary artery abnormalities in children with Kawasaki disease (KD). Despite this, there is lack of data on radiation dose in this group of children undergoing CTCA.

Research motivation

There is paucity of literature on radiation exposure in children with KD undergoing CTCA for coronary artery assessment.

Research objectives

To estimate the radiation dose exposure in children with KD undergoing CTCA for coronary artery assessment.

Research methods

Children with KD who underwent CTCA were either at presentation or on regular follow were included in the analysis. System generated radiation exposure dose length product (DLP in milligray-centimeters-mGy.cm) was recorded and effective radiation dose (millisieverts-mSv) was calculated by applying age adjusted conversion factors.

Research results

Total 85 children with median age of 5 years were scanned. Mean effective radiation dose was 0.83 mSv with radiation exposure significantly lower in infants (0.63 mSv) as compared to other age groups. CTCA demonstrated coronary artery abnormalities along the entire course of coronary arteries.

Research conclusions

CTCA is feasible with submillisievert radiation dose in most children with KD.

Research perspectives

CTCA has the potential to be an important adjunctive imaging modality in children with KD. To confirm our results multicentric study with larger sample size would be required.

FOOTNOTES

Author contributions: Bhatt MC and Singhal M contributed to the data interpretation, writing of first draft, review of literature, editing of manuscript and critical revision of manuscript at all stages; Pilania RK contributed to the patient management, data interpretation, writing of first draft, review of literature, editing of manuscript and critical revision of manuscript at all stages; Bansal SC, Khandelwal N, and Gupta P contributed to the review of literature and editing of manuscript; Singh S contributed to the patient management, review of literature, editing of manuscript, critical revision of manuscript at all stages; Bhatt MC and Singhal M contributed equally; Singhal M finally approved the manuscript.

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