

REVIEW

Open Access



Association of *ABCA1* gene with Coronary Artery Disease (CAD): an overview

Tanu Yadav¹, Arti Yadav¹, Asif Jafri² and Suchit Swaroop^{3*} 

Abstract

Background This review is a summarized study on CAD, CVD, atherosclerosis, and its association with the *ABCA1* gene. Only 13 clinical as well as epidemiological and peer-reviewed research papers published in the associated field were chosen for the review from out of 55 articles.

Main body The research papers have been collected and studied from PubMed, Research Gate, and Google Scholar search engines. In the study, it has been found that GWAS, cell culture, and data-based studies were done to figure out the relationship of the *ABCA1* gene with heart diseases. Blood samples were collected and diagnosed both biochemically and genetically to find out the lipid level and its functioning in the efflux of cholesterol and its effect and association with the *ABCA1* gene, and with CAD researchers.

Conclusions Dysregulation of DNA methylation can be re-expressed epigenetically. These studies of the *ABCA1* gene and its polymorphic variants would help in future research studies and further can develop new drugs and methods for the treatment of heart disease and CAD.

Keywords Coronary artery disease, *ABCA1* gene, Nucleotide binding domain, Polymorphic variants

Background

Among various heart diseases, CAD is responsible for the mortality and morbidity of patients worldwide. CAD develops due to the deposition of cholesterol leading to plaque in the arterial inner walls. Being a multi-factorial disease its association with certain genes such as *ABCA1* and *ABCG1* gene has also been studied [18]. The *ABCA1* gene belongs to the ATP-binding cassette genes (ABC) family, this uses ATP to transport any substrate from one organelle to another within a cell. These transporters have two conserved peptide motifs, Walker A and Walker B, on nucleotide-binding domains (NBD)

and specific amino acids between motifs for identification of the family [17]. NBD follows the Hexa helical transmembrane in the structural halves repeats of the *ABCA1* gene. *ABCA1* contains two extracellular domains, one between transmembranes 1 & 2 and the other one between transmembranes 7 & 8, these domains have two disulfide bonds necessary for the formation of HDL and sticking of apoA-I to the *ABCA1* [9]. *ABCA1* gene proved as an essential factor in the reverse transportation of cholesterol and thus shows an anti-atherosclerotic effect, i.e., no development of plaque in the inner arterial walls. *ABCA1* gene is 249 bp long with 49 exons located on chromosome 9q31.1 and shows susceptibility toward coronary artery disease [3]. Due to its anti-inflammatory receptive behavior inflammatory expression of factors such as IL-6, IL-1 β , and NEF- α were suppressed [12]. The relationship of the *ABCA1* gene SNPs with CAD has also been studied in previous research [4]. Clinical, and epidemiological studies were done on the *ABCA1* gene, its polymorphic variants, and their association with CAD and other heart diseases. Therefore, in this review article

*Correspondence:
Suchit Swaroop
ephlab19@gmail.com

¹ Experimental & Public Health Laboratory, Department of Zoology, University of Lucknow, Lucknow, Uttar Pradesh 226007, India

² Department of Zoology, Khwaja Moinuddin Chishti Language University, Lucknow 226013, India

³ Experimental & Public Health Laboratory, Department of Zoology, University of Lucknow, Lucknow 226007, India

vivid worldwide research performed on the ABCA1 gene and inferences drawn from those were discussed and tabulated (Table 1). ABCA1 mechanism is described in the form of figure (Fig. 1).

Main body

Molecular studies on the ABCA1 gene

Fouladseresht et al. [6] conducted a study on the Iranian population. This haplotypic investigation has identified a link between SNPs and CAD. The study's findings suggested a substantial correlation between the ABCA1 gene's polymorphic variants rs2422493 and rs1800976, which had T and G allelic frequencies, and the sensitivity of ABCA1 expression to CAD. The presence of the G allele at the third position in the haplotype T-G-X-A was thought to be a substantial risk factor for coronary artery disease (CAD) among susceptible individuals for the haplotypes T-G-G-A and T-G-A-A, or variant rs2230806 of the ABCA1 gene. Although CAD patients will be benefited from the C-C-G-G haplotype.

Samples from the Chinese armed police force were taken for six months in 2019 as part of [1], study of the Chinese population with 90 individuals with Premature Coronary Artery Disease (pCAD). The study examined the impact of methylation ABCA1 promoter on pCAD and its associations with lipid levels, inflammatory variables, and neutrophil extra traps (NETs) in patients with pCAD in China. The study concluded that the level of ABCA1 promoter methylation is positively correlated with the inflammatory cytokines (CRP, IL-1), and cfDNA/NETs. While the age and ABCA1 methylation status relationship were not significantly correlated in this study. Additionally, it has been noted that an individual's risk for pCAD can increase with a high rate of ABCA1 promoter methylation. This investigation might potentially produce a brand-new treatment for the regulation of DNA methylation for pCAD [1].

A study on 110 Iranian population was done, to check the severity development of CAD by studying the role of *ABCA1* DNA methylation. This research stated that DNA methylation frequency showed more significance in old-age CAD patients rather than in young CAD patients. It also found that *ABCA1* promoter methylation region and concentrations of plasma lipid have no significant association. Smoking affects the *ABCA1* methylation region too, in CAD patients was observed. This study limited itself in not assessing the gene expression levels and the cholesterol efflux activity assay was also not studied [8].

In case-control research that was just published in 2022 on a population of 260 people including both 120 cases and 20 more control people than the former.e.,140. The listing of CpG sites in base pairs to the transcriptional start site (TSS) and the positive distances

downstream of TSS were both influenced by relative distance. 37 sites were downgraded compared to the control group for analysis, whereas 14 methylated sites of the case group were increased. According to the study's findings, the lipid metabolic genes APOC3, CETP, and APOC1 exhibited lower methylation levels (hypomethylated) in the case than the control ones. Two of the APOA5 lipid metabolic gene's four CpG sites were hypomethylated, while two were hypermethylated. While of the LIPC gene 3 sites were methylated out of four sites. ANGPTL4, APOB, and PCSK9 genes had shown no significant role in methylation. APOC3, LIPC, CETP, and APOC1 were discovered significant in each sex (male & female) whereas APOA5 and ANGPTL4 were notified only in males [11].

Mahmoodi et al. [14], studied a population of 220 including subjects and control. This study aimed to investigate the prevalence and effect of polymorphic C-565 T of the ABCA1 gene on lipid profiles in Iranian CAD patients. This study indicated that ABCA1 C-565 T polymorphism is a significant risk factor for the development and severity of CAD in the TT homozygotic Iranian population. No significant association between ABCA1 C-565 T polymorphism and plasma lipid levels was evaluated. Net flux of cholesterol toward the liver from the vessel wall would get affected by reduced activity of the T allele of ABCA1 C-565 T polymorphism. This study had not performed some of the experiments, firstly, assay assessment of cellular cholesterol efflux activity, secondly, other polymorphic variants of the ABCA1 gene in relationship with CAD, and thirdly, undetermined ABCA1 gene expression level.

A pilot study was done in Mumbai, India 2017 in which 150 CAD patients were selected as subjects. This study reported the presence of 3112 SNPs of HDL-associated genes in the untranslated region (UTR), intronic, and exonic regions. A significant allelic association of the *ABCA1* gene with other genes such as APOA1, GALNT2, COBLL1, SLC39A8, TRPS1, MADD, UBASH3B, MVK, SCARB1, VDR, LACTB, LILRA3, and HNF4A was observed between subjects and controls. HDL-C levels were significantly increased in controls than in the subjects. HDL-C levels showed a correlation with variants of MADD, PPP1R3B, and LILRA3 genes. This study was limited to a sample consuming lipid-modifying drug(s), a heterogeneous population, and a lack of sufficient data for calculating the potentiality of risk factors (for instance lifestyle) [20].

In past research carried out during 2016–2017, on 82 patients including control and subjects. This study includes an analysis of EAT (epicardial adipose tissue) and SAT (subcutaneous adipose tissue) collected from the ostium of the right coronary artery and the

Table 1 Enlisted research studies performed by various authors on coronary artery disease (CAD) and its association with the ABCA1 gene and also include tools and techniques performed by them

References	Polymorphic variants studied	Primers	Techniques involved	Statistical tools applied in the study	The outcome of the study
[6]	ABCA1 / rs2422493 & rs1800976, rs2230806, rs1883025	NA	Genotyping, Gene Amplification	Hardy-Weinberg equilibrium. Pearson X ² testing. Binary logistic regression analysis	Polymorphic variants in haplotypes play a significant role in CAD
[1]	ABCA1	F: 5'-GGG TGG AGG GTA TAG TAG GT-3' R: 5'-AAC AAA TTC CAC TAA TAC CCTTAA CT-3'	Genotyping, DNA sequencing	SPSS19.0 software, Kolmogorov-Smirnov test, t-test, Mann-Whitney test, Chi-square test, Pearsons and nonparametric Spearman's rank correlation test	ABCA1 is associated with inflammatory factors, CRP, L-1 β and cDNA/NETs promote pCAD
[12]	ABCA1 / rs1800976, rs4149313, rs2230806	NA	Statistical study	Standard Deviation, Shapiro-Wilk test, one-way ANOVA analysis, χ^2 test, V.13.0 SPSS	
[8]	ABCA1	(Methylated F: AAT TTT ATT GGT GTT TTT GGT TGT C, methylated R: ATA TCCTAA ATT CCG CGA TCT ACG and (un-methylated F: AAT TTT ATT GGT GTT TTT GGT TGT T, un-methylated R: TAT CTT AAA ATC CAC AAT CTA CAT C)	Epigenetic study	Student t-test, Chi-square test or Fisher's exact tests, binary Logistic regression, SPSS 16 software	DNA methylation of ABCA1 is responsible for the development of CAD but not for the severity of CAD and has no significant association with plasma lipid concentrations
[1]	ABCA1, APOC3, CETP, APOC1, APOA5, LIPC	NA	Epigenetic study	SPSS package version 21.0, GraphPad Prism 5 Software, T-test analysis and standard deviation were performed	methylation levels of APOC3, CETP, and APOC1 gene promoters were found lower in CAD subjects while APOA5 and LIPC gene promoters were higher in CAD subjects, i.e., DNA methylated genes play a major role in CAD development
[7]	ABCA1 / rs111292742, rs9282541	NA	Epigenetic study	Ingenuity Variant Analysis	Variants of the ABCA1 gene are associated with the development of premature CAD
[4]	ABCA1 / C-565 T (rs2422493)	forward 5'-AAAGACTTCAAGGAC CCAAGCTT-3' and reverse 5'-CCTCAC A TTCCGAAAGCAATT-3'	Epigenetic analysis	SPSS Software, Student's t-test, chi-square test, or Fisher's exact tests, Multiple binary logistic regression	C-565 T (rs2422493) variant of ABCA1 independently & significantly, increase the risk for CAD
[20]	ABCA1 / rs72735008, GAIN12 / rs11620, PP1R3B / rs330921, APOA2 / rs6413453, MADD / rs8027027	NA	Genetic study	PLINK V.1.07 for minor allele frequencies Hardy-Weinberg equilibrium (HWE), linkage disequilibrium (LD), SPSS V.20 for normality of the phenotypical & genotypical comparative variables	low HDL-C patterns were observed in Indians and HDL-associated genetic loci to CAD

Table 1 (continued)

References	Polymorphic variants studied	Primers	Techniques involved	Statistical tools applied in the study	The outcome of the study
16	ABCA1	5'-AAC AAA TTC CAC TAA TAC CCT TAA CT-3' 5'-biotin-GGGTAG AGG GTAA TAG TAG GT-3' Seq 5'-AAC AAA TTC CAC TAA TAC CCT TAA CT-3' ABCG1 locus 1 5'-TGA GTTTAG GAG GTT AAG GAG AAA TT-3' 5'-biotin-CAA ATA AAC CAA CAA CAA AAC AAT AC-3' Seq 5'-TGA GTTTAG GAG GTT AAG GA-3'	Epigenetic study	Shapiro-Wilk test, t-tests, Mann-Whitney's U-test, Wilcoxon's signed-rank test, Holm-Bonferroni, Fisher's exact test, Spearman correlation, Statistical analysis by SPSS 17.0 software & R statistical computing environment	ABCA1 and ABCG1 DNA hypermethylated genes in EAT showed an association with CAD. Decreased ABCA1 mRNA expression in EAT results in multifocal atherosclerosis

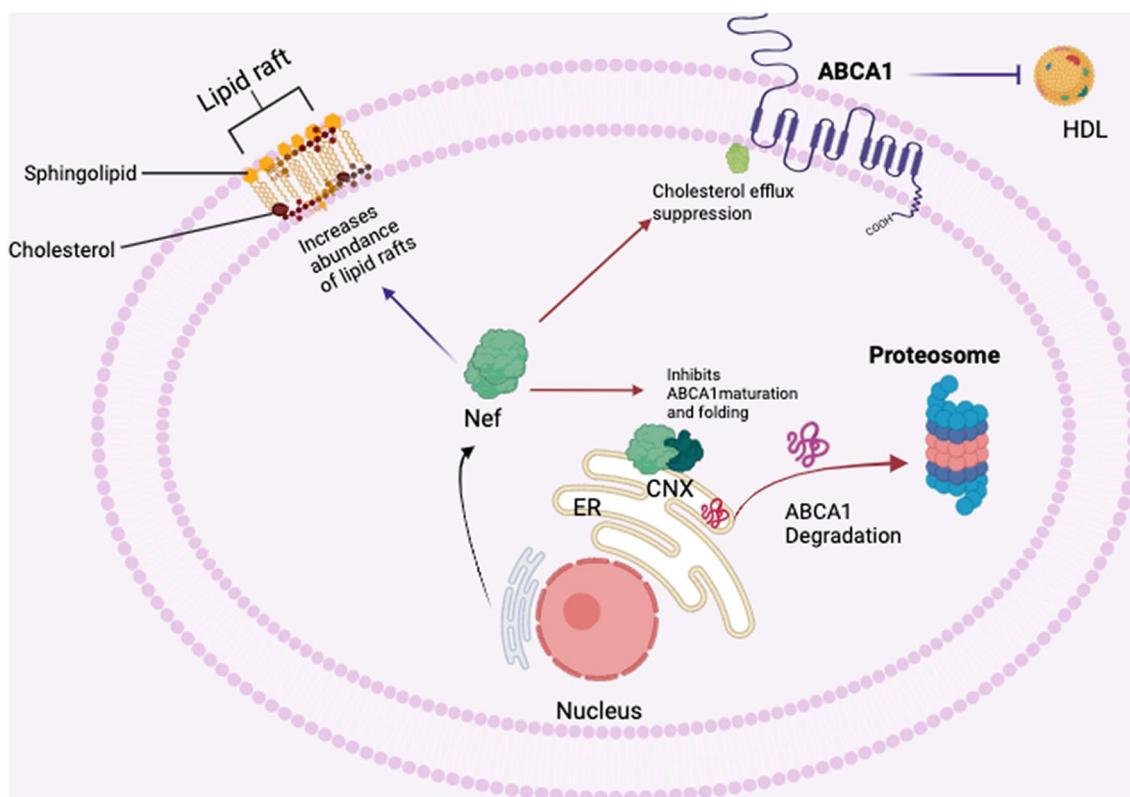


Fig. 1 An illustration showing how the ABCA1 gene's ability to produce HDL is inhibited. The ABCA1 gene, which encodes the cellular cholesterol transporter, is shown in this figure to be downregulated by Nef. Nef also alters the function of ABCA1 protein upgradation by blocking its interaction with the chaperone Calnexin (CNX), which results in the gene's degradation in the proteasome and prevents the production of HDL [10]

incision of the chest area samples, respectively. ABCA1 DNA hypermethylation is associated with CAD in EAT. Downregulation of the ABCA1 gene was observed for CAD with concomitant carotid artery disease or peripheral artery disease in EAT. Whereas the association of hypertriglyceridemia and obesity with DNA methylation levels at the ABCG1 cg27243685 locus in SAT. No significant association of mRNA levels with CAD and no correlation between DNA methylation and mRNA levels was observed. In macrophages, upregulation of ABCA1 mRNA levels and decreased levels of protein were reported. Gender differences in studied individuals show no association with changes in DNA methylation [16].

Epidemiological studies

An epidemiological study was done on 112,776 men and 145,476 women for 3 years (2014–2016) by diagnosing serum and plasma for assessment of total cholesterol, triglycerides, LDL-C (direct & sdLDL-C), HDL-C, apoA-I, apoB, glucose, insulin, adiponectin, hs-CRP, fibrinogen, myeloperoxidase (MPO), SGOT & SGPT levels of liver. HDL-C and TG plasma-associated variants- *ABCA1* rs111292742, *ABCA1* rs9282541, *LCAT* rs4986970, and

LPL rs268 were studied. It concluded that the defect in HDL-deficient male patients was due to malfunctioning of the *ABCA1* gene products, resulting in the inefficiency to efflux cholesterol onto HDL. Premature ASCVD had shown an association with HDL loss due to mutations or variants at the locus of *ABCA1* or *APOA1* in data-based sequencing [7].

Another study on a population of Nanchong, China had been done to analyze the polymorphic activity of the *ABCA1* gene in 442 CAD patients and 217 normal subjects. This study had also shown the outcome of CAD risk factors, and CAD's development with polymorphic genes. This study inference that rs1800976, the polymorphic form of *ABCA1* gene and its C allele, shows an association with hs-CRP and CysC plasma levels and with high CAD risk, whereas rs4149313 and rs2230806 variants show no significant association with CAD severity. The rs1800976 variant shows association with CAD but doesn't play any role in the expression of *ABCA1* gene regulation rather it shows association with the expression of the same gene, as it resides in *ABCA1* gene promoter region and affects the plasma levels of hs-CRP and CysC. [12].

In a CAPIRE study, 525 patients of age 45–75 who had a normal fraction of left ventricular ejection and with no coronary syndrome history were accepted for the study. It was concluded in the study that HDL functions instead of HDL levels had shown a significant association with coronary artery disease. SR-BI-mediated cholesterol efflux showed an association with decreased CAD like HDL while *ABCA1*-mediated cholesterol efflux had shown no improvement beyond the traditional risk factor in patients and neither helped in the prediction of cardiovascular events. This study suggested that HDL functions as a predictor of cardiovascular disease but shows no relation to improved atherosclerotic plaque characteristics [13].

A total of 860 patients were included in an observational study from January 2015 to February 2018 to examine the effectiveness of novel cardiovascular imaging methods. According to the study, ApoE-HDL-C and ApoC-III in HDL determine how serious a CVD is. Males were more at risk for CVD than females. Sex differences in the correlations between ApoE and ApoC-III can be studied in future too [19].

A study on the anti-atherosclerosis properties of apolipoprotein A1(apoA1). This study includes a half rise in the production of cholesterol involving *ABCA1*, the resultant rise of 30% in HDL-C level leads to a decrease in the risk of coronary artery disease by 35–50%. *ABCA1* gene promoter can be regulated by using many drugs such as myocardin, and rutaecarpine while for gene expression, microRNA and long noncoding RNA genome-wide techniques were incorporated after transcription for its regulation. Downregulated microRNA-17-5p (miR-17-5p) restricts lipid aggregation thereby upregulating the *ABCA1* gene. miR-17-5p allows *ABCA1* binding to the 3-untranslated region of miRNA. Further, enhanced RCT and cholesterol metabolism levels in patients with CVD can be identified by miR- 144 along with antisense oligodeoxynucleotides. It was studied that miR-33 can accelerate atherogenesis due to the inhibition of the *ABCA1* gene. The chemical compound N-benzothiazolyl-2-benzenesulfonamide acts as an up-regulator of the *ABCA1* gene and promotes cholesterol efflux by enhancing *ABCA1* mRNA [22].

The anti-inflammatory function of *ABCA1* was investigated in the treatment and prevention of coronary heart disorders. Inflammation occurs during atherosclerosis when cholesterol builds up in macrophage foam cells. This inflammatory reaction reduced macrophage *ABCA1*, which reduced cholesterol export and increased inflammation. The anti-inflammatory properties of HDL decrease the signaling of toll-like receptors. Migration of monocytes happens as a result of inflammation brought on by lipid buildup in the arteries, which causes

macrophage lipid accumulation to increase. It can be said that the activator of *ABCA1* efficiently reduces atherosclerosis/CAD [15].

Criteria for inclusion of subjects in the studies reviewed

The following inclusion criteria were accepted in the reviewed studies-

A blockage in the left bundle branch, an inversion in the T-wave of more than three millimeters in three or more leads, an elevation or depression of 0.5 mm or more in the ST-segment, an elevated level of troponin-T, a cardiac marker, and an elevated level of creatine-kinase muscle/brain in serum were used to identify and select CAD patients for research [6]. Subjects having stenosis of more than 50% were included. The trials also included individuals with low-risk factors and no CAD, individuals with multiple risk factors and no CAD, those with low-risk factors and CAD diffusion extended to >5 of the 16 segments, and individuals with multiple risk factors and CAD diffusion extending to >5 segments [13].

Exclusion criteria for subject selection in past studies

Exclusion criteria for the selection of CAD subjects used in various pieces of research are followed as-

Autoimmune disease patients or previous malignant neoplasms were not included in the study [6]. Cardiogenic attack, heart failure, liver and kidney malfunction, malignant tumor, and patients on treatment with drugs for lowering lipid level, coronary angiography, or tomography, and had stenosis results less than <50%, were excluded [1]. Subjects were excluded based on the intake of drugs that may affect their metabolism [12]. Subjects with a family history of CAD, solid tumor patients, and febrile disease were also excluded [8]. Lower stenosis report of the patients was also an important exclusion criterion [11]. Type 1 and type 2 diabetic patients were also excluded from the research [13].

Conclusions

In this review study, we explored CAD and its relationship to the *ABCA1* gene, which encodes a large membrane protein that performs reverse cholesterol transportation (RCT) activity in humans to transfer lipids to HDL and is also linked to apoA-1 [21]. The SNP rs2230806 of *ABCA1*'s K allele showed a strong connection with a lower incidence of CAD in the Asian population [5]. Dysregulation of DNA methylation can lead to cardiac conditions including CAD and CVD and can be epigenetically re-expressed. It can happen owing to mutation or in the absence of a methyl donor due to a shortage of nutrients in the body [2].

ABCA1 SNPs like rs1883025 have been linked to CHD via epigenetic alterations, according to Churilin et al. [4].

This review will assist new researchers in identifying diverse gene variants and their associations with coronary artery disease (CAD) and lipid levels in the body, as well as in the development of new hypotheses for a variety of heart disorders and the study of epigenetics.

Abbreviations

CAD	Coronary artery disease
CHD	Coronary heart disease
CVD	Coronary vascular disease
CAC	Coronary artery calcium
EAT	Epicardial adipose tissue
SAT	Subcutaneous adipose tissue
NBD	Nucleotide binding domain
MPO	Myeloperoxidase
CTCTA	Coronary computed tomography and angiography
SGOT	Serum glutamic oxaloacetic transaminase
SGPT	Serum glutamic pyruvic transaminase

Acknowledgments

Not Applicable.

Author contributions

All authors contributed to this work. SS & TY conceived and designed the study strategy and quality assessment; TY independently completed the processes of the article search, article assessment, data extraction, and wrote the manuscript. AY edited the article. AJ completed the second time article analysis. All authors reviewed and approved the final manuscript.

Funding

No funding agency has contributed to this article.

Availability of data and materials

The present review article data are from publicly accessible sites and the data that supports the findings of this study are available on request from the corresponding author.

Declarations

Ethics approval and consent participation

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Received: 18 December 2022 Accepted: 21 September 2023

Published online: 11 November 2023

References

- An F, Liu C, Wang X, Li T, Fu H, Bao B, Cong H, Zhao J (2021) Effect of ABCA1 promoter methylation on premature coronary artery disease and its relationship with inflammation. *BMC Cardiovasc Disord*. <https://doi.org/10.1186/s12872-021-01894-x>
- Braun KVE (n.d) Nutrition and cardiometabolic health: the role of DNA methylation, 2017. ISBN: 978-94-6361-053-7
- Cao X, Yin R, Huang F, Wu J, Chen W (2016) Chromosome 9p21 and ABCA1 genetic variants and their interactions on coronary heart disease and ischemic stroke in a Chinese han population. *Int J Mol Sci*. <https://doi.org/10.3390/ijms17040586>
- Churilin MI, Kononov SI, Luneva YV, Kazanov VA, Azarova IE, Klyosova EY, Bykanova MA, Paschoalini G, Kharchenko AV, Zhabin SN, Bushueva OY, Povetkin SV, Mal GS, Kovalev AP, Solodilova MA, Polonikov AV (2020) Polymorphisms of intracellular cholesterol transporters genes: relationship to blood lipid levels, carotid intima-media thickness, and the development of coronary heart disease. *Russ J Genet* 56(2):234–241. <https://doi.org/10.1134/S10227954200020040>
- Fan Q, Zhu Y, Zhao F (2020) Association of rs2230806 in ABCA1 with coronary artery disease: an updated meta-analysis based on 43 research studies. *Medicine (United States)*. <https://doi.org/10.1097/MD.00000000000018662>
- Fouladseresht H, Khazaee S, JavadZibaeenezhad M, Hossein Nikoor M, Khosropanah S, Doroudchi M (2020) Association of ABCA1 haplotypes with coronary artery disease. *Lab Med* 51(2):157–168. <https://doi.org/10.1093/labmed/lmz031>
- Geller AS, Polisecki EY, Diffenderfer MR, Asztalos BF, Karathanasis SK, Hegle RA, Schaefer EJ (2018) Genetic and secondary causes of severe HDL deficiency and cardiovascular disease. *J Lipid Res* 59(12):2421–2435. <https://doi.org/10.1194/jlr.M088203>
- Guay SP, Brisson D, Munger J, Lamarche B, Gaudet D, Bouchard L, Ghaznavi H, Mahmoodi K, Soltanpour MS, Kiani AA, Soltanpour MS (2018) Association study between DNA methylation and genetic variation of APOE gene with the risk of coronary artery disease. *Mol Biol Res Commun* 7(4):173–179. <https://doi.org/10.4161/epi.19633>
- Ishigami M, Ogasawara F, Nagao K, Hashimoto H, Kimura Y, Kioka N, Ueda K (2018) Temporary sequestration of cholesterol and phosphatidylcholine within extracellular domains of ABCA1 during nascent HDL generation. *Sci Rep* 8(1):2–11. <https://doi.org/10.1038/s41598-018-24428-6>
- Jacobo-albavera L, Dominguez-Perez M, Medina-leyte DJ, Gonzalez-Garido A, Villarreal-Molina T (2021) The role of the ATP-binding cassette A1 (ABCA1) in human disease. *Int J Mol Sci* 22:1593. <https://doi.org/10.3390/ijms22041593>
- Li W, Wang Y, Lian F (2022) Association of lipid metabolism related gene promoter methylation with risk of coronary artery disease. <https://doi.org/10.21203/rs.3.rs-1338296/v1s>
- Lu Z, Luo Z, Jia A, Muhammad I, Zeng W, Shigammo A, Chen X, Song Y (2019) Effects of ABCA1 gene polymorphisms on risk factors, susceptibility, and severity of coronary artery disease. *Postgrad Med J*. <https://doi.org/10.1136/postgradmedj-2019-136917>
- Magnoni M, Andreini D, Pirillo A, Ubaldi P, Latini R, Catapano AL, Maggioni AP, Norata GD (2022) Predictive value of HDL function in patients with coronary artery disease: relationship with coronary plaque characteristics and clinical events. *Ann Med* 54(1):1036–1046. <https://doi.org/10.1080/07853890.2022.2063374>
- Mahmoodi K, Kamali K, Ghaznavi H, Soltanpour MS (2018) The C-565T polymorphism (Rs2422493) of the ATP-binding cassette transporter a1 gene contributes to the development and severity of coronary artery disease in the Iranian population. *Oman Med J* 33(4):309–315. <https://doi.org/10.5001/omj.2018.57>
- Matsuo M (2022) ABCA1 and ABCG1 as potential therapeutic targets for the prevention of atherosclerosis. *J Pharmacol Sci* 148(2):197–203. <https://doi.org/10.1016/j.jphs.2021.11.005>
- Miroshnikova VV, Panteleeva AA, Pobozheva IA, Razgildina ND, Polyakova EA, Markov AV, Belyaeva OD, Berkovich OA, Baranova EI, Nazarenko MS, Puzyrev VP, Pchelina SN (2021) ABCA1 and ABCG1 DNA methylation in epicardial adipose tissue of patients with coronary artery disease. *BMC Cardiovasc Disord* 21(1):1–12. <https://doi.org/10.1186/s12872-021-02379-7>
- Oram JF, Lawn RM (2001) ABCA1: The gatekeeper for eliminating excess tissue cholesterol. *J Lipid Res* 42(8):1173–1179
- Sharma P, Garg G, Kumar A, Mohammad F, Ramesh S (2014) Genome-wide DNA methylation profiling for epigenetic alteration in coronary artery disease patients. *Gene* 541(1):31–40. <https://doi.org/10.1016/j.gene.2014.02.034>
- Sorokin AV, Patel N, Abdelrahman KM, Ling C, Reimund M, Graziano G, Sampson M, Playford MP, Dey AK, Reddy A, Teague HL, Stagliano M, Amar M, Chen MY, Mehta NN, Remaley AT (2022) Complex association of apolipoprotein E-containing HDL with coronary artery disease burden in cardiovascular disease. *JCI Insight*. <https://doi.org/10.1172/jci.insight.159577>

20. Stanley A, Ponde CK, Rajani RM, Ashavaid TF (2017) Association between genetic loci linked to HDL-C levels and Indian patients with CAD: a pilot study. *Heart Asia* 9(1):1–5. <https://doi.org/10.1136/heartasia-2016-010822>
21. Wang S, Smith JD (2014) ABCA1 and nascent HDL biogenesis. *BioFactors* 40(6):547–554. <https://doi.org/10.1002/biof.1187>
22. Xu X, Song Z, Mao B, Xu G (2022) Review article apolipoprotein A1-related proteins and reverse cholesterol transport in antiatherosclerosis therapy : recent progress and future perspectives. *Hindawi Cardiovasc Ther* 2022:4610834. <https://doi.org/10.1155/2022/4610834>

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Submit your manuscript to a SpringerOpen® journal and benefit from:

- Convenient online submission
- Rigorous peer review
- Open access: articles freely available online
- High visibility within the field
- Retaining the copyright to your article

Submit your next manuscript at ► springeropen.com

[Back](#)

METEOROLOGICAL AND GEOSPATIAL ANALYSIS-BASED INTEGRATED MACHINE LEARNING FOR ACCURATE AIR QUALITY FORECASTING

[Journal of Environmental Protection and Ecology](#) • Article • 2024

[Sharma, Pradosh Kumar^a](#); [Mamatha K.^b](#); [Patankar, Nikhil S.^c](#); [Selvam N.^d](#); [Dwivedi, Nidhi^e](#); [+2 authors](#)

^aChinmaya Degree College, BHEL, Haridwar, India

[Show all information](#)

11 86th percentile

Citations

1.93

FWCI

[Full text](#) [Export](#) [Save to list](#)

Document

Impact

Cited by (11)

References (18)

Similar documents

Abstract

In light of the growing environmental problems caused by low air quality, this investigation offers a thorough approach to precise air quality forecasting. The goal of the research effort is to disentangle the intricate network of variables affecting air quality by fusing state-of-the-art machine learning algorithms with meteorological and geographic data. The investigation acknowledges both man-made and natural air pollution sources, among other diverse sources. The burning of fossil fuels, industry, farming, waste disposal, deforestation, automobile traffic, and indoor sources are all included in the following list. To create accurate forecasting models, a comprehensive data collection process is employed, which includes historical and current datasets from weather sources and monitoring stations. To comprehend spatial connections and trends, spatial analysis is incorporated using Geographic information system (GIS) capabilities. Continuous hyperparameter tuning is carried out while model validation, using measures like Mean absolute error (MAE) and Root mean squared error (RMSE), assures accuracy. In order to provide dynamic forecasting, the created system is integrated into a real-time framework and continuously assimilates updated meteorological and geographical data. Access to stakeholders is facilitated by an intuitive interface, which highlights the environmental consequences of changes in air quality. Working

together with environmental groups, research institutes, and meteorological agencies promotes data exchange and ongoing model improvement. With an emphasis on the effects on the environment, this integrated method offers a comprehensive solution for precise and fast air quality forecasts. This research helps to proactive decision-making in pollution control and sustainable environmental practices by addressing the important requirement for effective environmental management techniques. © 2024, Scibulcom Ltd.. All rights reserved.

Author keywords

air quality forecasting; environmental impacts; geospatial integration; machine learning models; meteorological analysis; sustainable environmental practices

Indexed keywords

GEOBASE Subject Index

accuracy assessment; air quality; data set; environmental impact; environmental management; forecasting method; machine learning; meteorology; spatial analysis; sustainability

Corresponding authors

Corresponding author

A. Rajaram

Affiliation Department of Electronics and Communication Engineering, E. G. S. Pillay Engineering College, Tamil Nadu, Nagapattinam, 611 002, India

Email address drrajaram@eqspec.org

© Copyright 2024 Elsevier B.V. All rights reserved.

Abstract

Author keywords

Indexed keywords

Corresponding authors

About Scopus

[What is Scopus](#)

[Content coverage](#)

[Scopus blog](#)

[Scopus API](#)

[Privacy matters](#)

Language

[日本語版を表示する](#)

[查看简体中文版本](#)

[查看繁體中文版本](#)

[Просмотр версии на русском языке](#)

Customer Service

[Help](#)

[Tutorials](#)

[Contact us](#)

ELSEVIER

[Terms and conditions](#) ↗ [Privacy policy](#) ↗ [Cookies settings](#)

All content on this site: Copyright © 2026 Elsevier B.V. ↗, its licensors, and contributors. All rights are reserved, including those for text and data mining, AI training, and similar technologies. For all open access content, the relevant licensing terms apply.

 RELX™

[Back](#)

Artificial intelligence and blockchain technologies for smart city

Intelligent Green Technologies for Sustainable Smart Cities • Book Chapter • 2022 •

DOI: 10.1002/9781119816096.ch15

Singh, Jagendra^a ; Sajid, Mohammad^b; Gupta, Suneet Kumar^a; Haidri, Raza Abbas^c

^aSchool of Engineering and Applied Sciences, Bennett University, Greater Noida, India

[Show all information](#)

This document is one of the chapters of a book series. [See all chapters](#)

77 99th percentile

Citations

21.44

FWCI

[Full text](#) [Export](#) [Save to list](#)

Document

Impact

Cited by (77)

References (27)

Similar documents

Abstract

In this digital age of rapid communication, the advances of emerging technologies can be used for making smart city as intelligent society. Specially, the speedy acceptance of artificial intelligence (AI) and blockchain technologies have guided a paradigm that is shifting to a new dimension called as digital ecosystem for smart city. A large number of AI and applications of blockchain guarantee resolutions for challenges in the fields varying from financial services, and threat management to cryptocurrency, and from social and public services to Internet of Things (IoT). Moreover, the conjunction of blockchain and AI technologies is transforming the network of smart city architecture for developing sustainable ecosystems. When we try to achieve the goal of developing smart cities, the innovations in technologies created both challenges and opportunities. This chapter presents a broad literature examination to the safety problems and the challenges, which influence the blockchain utilization in developing sustainable and smart societies. Our work represents a comprehensive dialogue of various vital issues for coming together for AI and blockchain knowledge, which help us to develop smart societies. Therefore, we talk about the solutions of security issues of blockchain and summarize the

important concepts that need to be utilized to develop many AI and blockchain-centered smart transportation techniques. Moreover, we review the problems that stay public and our forthcoming research directions, this contains new proposals for security and future regulations for developing a smart society with sustainable ecosystem. © 2022 Scrivener Publishing LLC.

Author keywords

Artificial intelligence; Blockchain technologies; Green computing; Internet of thing; Smart city; Smart transport system

Corresponding authors

Corresponding
author

J. Singh

Affiliation

School of Engineering and Applied Sciences, Bennett University, Greater Noida,
India

Email address

jagendra.singh@bennett.edu.in

© Copyright 2023 Elsevier B.V., All rights reserved.

Abstract

Author keywords

Corresponding authors

About Scopus

[What is Scopus](#)

[Content coverage](#)

[Scopus blog](#)

[Scopus API](#)

[Privacy matters](#)

Language

[日本語版を表示する](#)

[查看简体中文版本](#)

[查看繁體中文版本](#)

[Просмотр версии на русском языке](#)

Customer Service

[Help](#)

[Tutorials](#)

[Contact us](#)

ELSEVIER

[Terms and conditions](#) ↗ [Privacy policy](#) ↗ [Cookies settings](#)

All content on this site: Copyright © 2026 [Elsevier B.V.](#) ↗, its licensors, and contributors. All rights are reserved, including those for text and data mining, AI training, and similar technologies. For all open access content, the relevant licensing terms apply.



[Back](#)

International Export Orientation and Firm's Performance: Evidence from Enterprise Survey Data of India

[Journal of Asia-Pacific Business](#) • Article • 2018 • DOI: 10.1080/10599231.2018.1525248

[Ali, Jaber](#)^a ; [Yusuf, Nadia](#)^b ; [Ali, Tabassum](#)^c

^a National Institute of Agricultural Extension Management (MANAGE), Hyderabad, Telangana, India

[Show all information](#)

2 26th percentile

Citations

[Full text](#) [Export](#) [Save to list](#)

[Document](#)

[Impact](#)

[Cited by \(2\)](#)

[References \(53\)](#)

[Similar documents](#)

Abstract

This study aims at analyzing the performance of firms by international export orientation vis-à-vis domestic orientation, based on World Enterprise Survey Data of 9,281 firms of India. Simple statistical techniques such as chi-squared test, ANOVA, and regression model have been used to analyze the data with the help of SPSS version 20.0. Chi-square statistics indicate that there is significant difference in enterprise characteristics by business orientation domestic versus export-oriented businesses. Result of the ANOVA indicates a significant difference in business performance between export versus domestic orientation of firms in terms of sales and employment growth rates. Export-oriented enterprises perceive comparatively fewer obstacles than domestic enterprises. Regression analysis indicates that enterprise characteristics, performance indicators, and business obstacles have influence on export orientation of the firms. This study provides insights on differences in firms' performance across business orientations and factors affecting the internationalization of business. This study can be helpful in designing policies for promoting export-oriented enterprises in a focused manner. © 2018, © 2018 Taylor & Francis Group, LLC.

Author keywords

Indexed keywords

Regional Index

India

GEOBASE Subject Index

business; employment; export; globalization; growth rate; industrial performance

Corresponding authors

Corresponding author

J. Ali

Email address jabirali@live.in

© Copyright 2019 Elsevier B.V., All rights reserved.

Abstract

Author keywords

Indexed keywords

Corresponding authors

About Scopus

What is Scopus

Content coverage

Scopus blog

Scopus API

Privacy matters

Language

[日本語版を表示する](#)

[查看简体中文版本](#)

[查看繁體中文版本](#)

[Просмотр версии на русском языке](#)

Customer Service

[Help](#)

[Tutorials](#)

[Contact us](#)

ELSEVIER

[Terms and conditions](#) ↗ [Privacy policy](#) ↗ [Cookies settings](#)

All content on this site: Copyright © 2026 [Elsevier B.V.](#) ↗, its licensors, and contributors. All rights are reserved, including those for text and data mining, AI training, and similar technologies. For all open access content, the relevant licensing terms apply.

 **RELX™**