Atlas of Genetics and Cytogenetics in Oncology and Haematology

OPEN ACCESS JOURNAL

INIST-CNRS

Gene Section

Review

HNRNPA1 (Heterogeneous Nuclear Ribonucleoprotein A1)

Murat Erdem, Ibrahim Özgül, Ayse Elif Erson-Bensan

Department of Biological Sciences, Middle East Technical University, Ankara, TURKEY, E-mail: erson@metu.edu.tr; merdem@metu.edu.tr; iozgul@metu.edu.tr

Published in Atlas Database: October 2018

Online updated version : http://AtlasGeneticsOncology.org/Genes/HNRNPA1ID43803ch12q13.html

Printable original version : http://documents.irevues.inist.fr/bitstream/handle/2042/70455/10-2018-HNRNPA1ID43803ch12q13.pdf

DOI: 10.4267/2042/70455

Abstract

Heterogeneous nuclear ribonucleoprotein (HNRNPA1) gene maps to chromosome 12, plus strand and has 13 exons and 12 introns. There are three reported transcripts due to the alternative splicing.

HNRNPA1 is one of the most abundant and ubiquitously expressed nuclear proteins. HNRNPA1 is a member of RNA-binding protein family comprising of 20 members in humans (Dreyfuss, 1993; Pinol-Roma, Choi, Matunis, Dreyfuss, 1988). HNRNPA1 has diverse roles in RNA splicing, telomere length maintenance, miRNA maturation and mRNA transport from nucleus to cytoplasm.

Keywords

HNRNPA1; RNA-binding protein; RNA splicing; telomere length maintenance; miRNA maturation; mRNA transport

Identity

Other names: HNRPA1, ALS20, hnRNP A1, hnRNP-A1, IBMPFD3, UP 1, HNRPA1L3

HGNC (Hugo): HNRNPA1

Location: 12q13.13

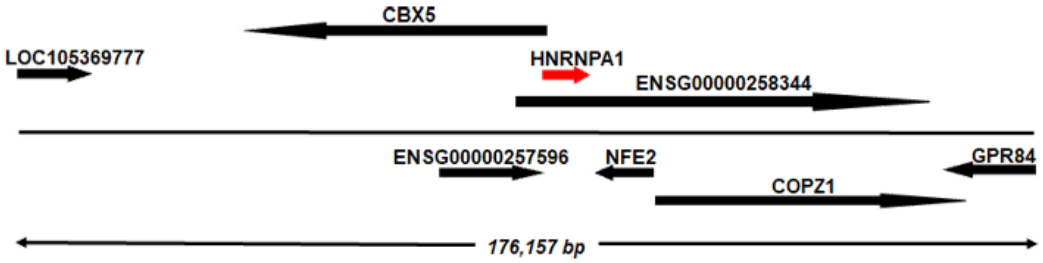
Local order

From telomere to centromere: LOC105369777, CBX5, ENSG00000257596, HNRNPA1, NFE2, ENSG00000258344, COPZ1, GPR84

DNA/RNA

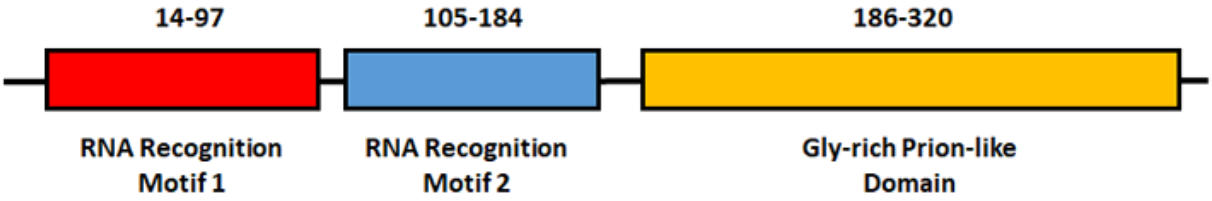
Note

HNRNPA1 gene consists of 13 exons and 12 introns. The gene maps to 12q13.13 and is 6399 bps long (NCBI Reference Sequence: NC_000012.12: 54280690-54287088). Highlighted in red is the protein coding sequence from exons 1-10. (Figure 2)



Local order of HNRNPA1 together with neighboring upstream and downstream genes on chromosome 12. The direction of arrows indicates direction of transcription and arrow sizes approximate gene sizes.

HNRNPA1 gene has 13 exons and 12 introns. Numbers indicate the exons. Red exons show protein-coding regions while blue color represents untranslated regions.



HNRNPA1 has three functional regions; two RNA-recognition motifs and one Glycine-rich Prion like domain. Numbers above the bars indicate amino acids harboring the domains.

Description

The HNRNPA1 gene is 6399 bases long and is on the plus strand. HNRNPA1 gene has 13 exons (Jean-Philippe et al., 2013).

Transcription

HNRNPA1 produces two coding transcripts (Exon 1-11). The difference between these coding transcripts is the presence or absence of exon 8 (only longer mRNA contains exon 8). A third one was reported as a potential non-coding transcript (Mendell et al, 2004). This non-coding RNA transcript has exons 12 and 13, and it does not contain exon 8.

Pseudogene

There are 75 pseudogenes of HNRNPA1 which are: HNRNPA1P1, HNRNPA1P10, HNRNPA1P11, HNRNPA1P12, HNRNPA1P13, HNRNPA1P14, HNRNPA1P15, HNRNPA1P16, HNRNPA1P17, HNRNPA1P18, HNRNPA1P19, HNRNPA1P2, HNRNPA1P20, HNRNPA1P21, HNRNPA1P22, HNRNPA1P23, HNRNPA1P24, HNRNPA1P25, HNRNPA1P26, HNRNPA1P27, HNRNPA1P28, HNRNPA1P29, HNRNPA1P3, HNRNPA1P30, HNRNPA1P31, HNRNPA1P32, HNRNPA1P33, HNRNPA1P35, HNRNPA1P36, HNRNPA1P37, HNRNPA1P38, HNRNPA1P39, HNRNPA1P4, HNRNPA1P40, HNRNPA1P42, HNRNPA1P43, HNRNPA1P44, HNRNPA1P45, HNRNPA1P46, HNRNPA1P47, HNRNPA1P48, HNRNPA1P49, HNRNPA1P5, HNRNPA1P50, HNRNPA1P51, HNRNPA1P52, HNRNPA1P53, HNRNPA1P54, HNRNPA1P55, HNRNPA1P56, HNRNPA1P58, HNRNPA1P59, HNRNPA1P6, HNRNPA1P60, HNRNPA1P61, HNRNPA1P62, HNRNPA1P63, HNRNPA1P64, HNRNPA1P65, HNRNPA1P66, HNRNPA1P67, HNRNPA1P68, HNRNPA1P69, HNRNPA1P7, HNRNPA1P70, HNRNPA1P71, HNRNPA1P72, HNRNPA1P74, HNRNPA1P75, HNRNPA1P76, HNRNPA1P77, HNRNPA1P8, HNRNPA1P9, LOC100421349 and LOC100421402(NCBI,2018).

Protein

Note

HNRNPA1 gene encodes a 372 amino acid protein. The protein is a member of heterogeneous nuclear ribonucleoproteins (hnRNPs) and has an estimated molecular weight of 38-39 kDa (Jean-Philippe, Paz, Caputi, 2013).

Description

HNRNPA1 has two RNA recognition motifs; RRM1 and RRM2.

These domains are known for binding to single-stranded RNAs (Dreyfuss, Swanson, Piñol-Roma, 1988).

HNRNPA1 also possesses a prion-like domain (PLD).

This domain is reported in RNA binding proteins that have been associated with neurodegenerative disorders such as Amyotrophic Lateral Sclerosis (Kim et al., 2013).

In addition, glycine-rich region mediates subcellular localization and protein-protein interactions (Han, Tang, Smith, 2010).

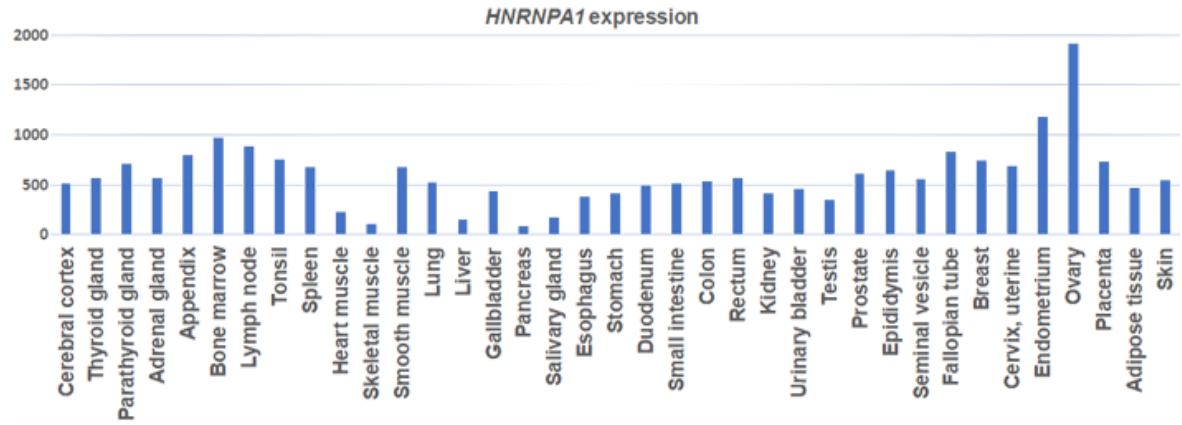
Expression

HNRNPA1 mRNA is expressed in all human tissues including brain, skin, lung, breast and kidney (The Human Protein Atlas, 2018).

Localisation

HNRNPA1 protein is mainly nuclear; however, under certain conditions the protein is also present in the cytosol (Roy et al., 2014).

In fact, HNRNPA1 may shuttle between nucleus and cytoplasm along with mRNAs (Jønson et al., 2007).



Expression of HNRNPA1 in different types of tissues is shown (The Human Protein Atlas, 2018).

Function

HNRNPA1 has a very broad range of reported functions including transcriptional regulation, alternative splicing, mRNA transport, translation and miRNA processing. Most surprisingly, HNRNPA1 can interact with certain promoters and induce transcriptional repression or activation of target genes. VDR (Vitamin D receptor) (H. Chen, Hewison, Hu, Adams, 2003), FGG (γ-fibrinogen) (Xia, 2005) and TK1 (thymidine kinase) (Lau et al., 2000) promoters are transcriptionally repressed while APOE promoter is activated by HNRNPA1 (Campillos et al., 2003).

HNRNPA1 has an important role in mRNA splicing. The protein modulates alternative splicing of various genes including INSR (Insulin Receptor) (Talukdar et al., 2011), BRCA1 (Breast Cancer 1) (Goina, Skoko, Pagani, 2008), PKM (Pyruvate Kinase M1/2) (David, Chen, Assanah, Canoll, Manley, 2010) and its own HNRNPA1 mRNA (Hutchison, LeBel, Blanchette, Chabot, 2002). mRNA splicing is modulated by HNRNPA1 by exon skipping and splice site repression (Jean-Philippe et al., 2013).

HNRNPA1 contributes to telomere regulation by promoting telomerase activity via binding to telomeric sequences, potentially as an auxiliary factor for the telomerase enzyme (Zhang, Manche, Xu, Krainer, 2006).

HNRNPA1 has roles in mRNA transport between nucleus and cytoplasm. Although the exact mechanism is unknown, HNRNPA1 binds to poly(A) tailed mRNAs both in the nucleus and cytoplasm (Mili, Shu, Zhao, Pinol-Roma, 2001), and possibly aid their transfer through nuclear pores (Piñol-Roma Dreyfuss, 1992).

Another function attributed to HNRNPA1 is during translation. HNRNPA1 binds to internal ribosomal entry sites (IRES) that initiates 5' cap-independent translation of certain cellular and viral mRNAs (such as, MYC), CSDE1 (Upstream of NRAS), CCND1 (Cyclin D1), VEGFA (Vascular Endothelial Growth Factor), FGF2 (Fibroblast Growth Factor), APAF1, and XIAP mRNAs (Cammas et al. 2007). In addition, the HIV-1 IRES is stimulated by hnRNPA1 (Martènez-Salas, Piñeiro, Fernández, 2012).

In addition to mRNA processing and transport , HNRNPA1 interacts directly and specifically with C-terminal region of NF-kB alpha inhibitory subunit via its RNA-binding domain (between residues 95 and 207) resulting in the activation of nuclear factor k B (Hay, Kemp, Dargemont, Hay, 2001).

The exact mechanism of HNRNPA1 and NF-kB interaction is not completely understood. However, in cells lacking HNRNPA1, activation of NF-kB is defected. When HNRNPA1 loss is rescued, an effective NF-kB response to signal induction is observed only upon ligand induction.

As for the microRNA processing, HNRNPA1 binds to the terminal loop of pri-miR-18a, and facilitates MIR18A production by creating favorable cleavage site for DROSHA (Guil Cáceres, 2007). In contrast, HNRNPA1 negatively affects MIRNLET7A1 (let-7a) biogenesis. HNRNPA1 binds to terminal loop of pri-let-7a-1 and interferes with the binding of KHSRP (component of both Drosha and Dicer complexes, known to promote let-7a biogenesis); hence, inhibiting processing of pri-let-7a by Drosha (Michlewski Cáceres, 2010).

Homology

HNRNPA1 gene has homologs across Amniota including P. troglodytes, M. mulatta, B. taurus, R. norvegicus, G. gallus, M. musculus and H. sapiens (NCBI HomoloGene, 2018).

There is also a well-studied HNRNPA1 homolog in D. melanogaster called Hrp36 (Singh Lakhotia, 2012).

In total, there are 97 species including invertebrates that have genes orthologous to A1 (NCBI Ensembl, 2018).

Mutations

Note

Up to 106 substitution mutations were reported in the HNRNPA1 gene in 42,067 cancer patients.
Reported mutations are generally missense mutations (70 of 106). There are also 4 nonsense mutations, 30 synonymous substitutions and 2 frameshift deletions (COSMIC database, 2018). One of the frameshift deletions found in cancer patients is discovered in the Sanger Institute Cancer Genome Project (study ID :COSU652) while the other is discovered in 619 incident colorectal cancer patients in the study conducted by Giannakis et al(2016).
Yu et al. (2018) also reported a recessive frameshift mutation in HNRNPA1 leading to deregulation of cardiac transcription network and multiple signaling pathways, including Bone Morphogenetic Protein, Notch and Fibroblast growth factor signaling.

Implicated in

Top note
HNRNPA1 has been implicated in diverse diseases.

Amyotrophic Lateral Sclerosis (ALS)

Note
Immunohistochemistry and immunofluorescence results showed that HNRNPA1 protein was decreased in the nuclei of neurons and the significant loss of HNRNPA1 in motor neurons with concomitant cytoplasmic aggregation in ALS cases while HNRNPA1 was mainly located in nucleus of motor neurons in normal cases (Honda et al., 2015). Mutations in prion-like domain (PrLD), enriched in uncharged polar amino acids and glycine, promote excess incorporation of HNRNPA1 into stress granules and cause the formation of cytoplasmic inclusions in animal models (H. J. Kim et al., 2013b). Whole-exome sequencing conducted by Liu et al.(2016) showed a missense mutation in HNRNPA1 in Flail-Arm ALS patients leading to cytoplasmic inclusions that co-localized with stress granules in Flail-Arm ALS.

Breast Cancer

Note
Invasive breast cancer cells (MDA-MB-231) express the CD44v6 variants, which are regulated by HNRNPA1. Downregulation of HNRNPA1 induces a significant change in the expression levels of CD44 isoforms through alternative splicing. Silencing of HNRNPA1 significantly induced cell death and caused a decrease in cell invasion in the MDA-MB-231 cells (Loh et al., 2015). HNRNPA1 silencing through siRNAs significantly lowers the cell proliferation in MDA-MB-231 cells (Otsuka, Yamamoto, Ochiya, 2018).

Prognosis
In basal-like breast cancer, Kaplan-Meier survival analysis showed that patients (309 samples) showing high HNRNPA1 expression, had an distinctively shorter relapse-free survival than patients (309 samples) expressing low level of HNRNPA1 and that patients (121 samples) showing high HNRNPA1 expression had a shorter overall survival than patients (120 samples) with low level of HNRNPA1 expression. (Otsuka, Yamamoto, Ochiya, 2018).

Cervical Carcinoma

Note
HNRNPA1 has higher expression in cervical carcinoma compared with normal tissue samples in 32 patients with cervical cancer (Y. J. Kim et al., 2017).
HNRNPA1 expression is upregulated during differentiation of virus-infected epithelial cells in monolayer and 3D cell cultures. HNRNPA1 interacts directly with the Human papillomavirus type 16 (HPV16) late regulatory element (LRE) (which has an important role in temporally controlling virus late gene expression during epithelial differentiation) in the nucleus of differentiated W12 cells in vitro and may facilitate the alternative splicing of late transcripts of virus in differentiated epithelial cells (Cheunim, Zhang, Milligan, McPhillips, Graham, 2008).

Colon Cancer

Note
HNRNPA1 mRNA is overexpressed in 40-78% of colon cancer stages, compared with normal colon (Ubagai, Fukuda, Tsuchiya, 2005).
A cell line based study showed HNRNPA1 to be suppressed by MIR18a in SW620 cells through autophagolysosomal degradation and thus, HNRNPA1 silencing resulted in the suppression of colon cancer cell progression (Fujiya et al., 2014).

Gastric Cancer (GC)

Note
GC tissues have elevated levels of HNRNPA1 protein compared with normal tissues. HNRNPA1 silencing significantly prevented anchorage-dependent growth in GC cells and HNRNPA1 was important to cell growth and progression of GC. HNRNPA1 knockdown caused reduction in cell growth, invasion, migration and reversal of EMT (Epithelial to Mesenchymal Transition) in GC cells. Collectively, these results pointed out that HNRNPA1 may have a pivotal role in GC cell invasion and metastasis (Chen et al., 2018).

Hepatocellular Carcinoma (HCC)

Note
High expression of HNRNPA1 was reported in the highly metastatic HCC cell lines and in tumor tissues of patients with recurrent HCC. HNRNPA1 silencing reduced cell invasion in highly metastatic HCC cells while overexpression of HNRNPA1 caused a significant increase in invasive behavior of

poorly metastatic HCC cells HNRNPA1 was reported to regulate the invasive capacity of HCC cells through regulating the CD44v6 expression(Zhou et al., 2013).

Lung Cancer

Note

The HNRNPA1 protein expression was reported to be upregulated in most tissue samples from lung cancer patients by immunohistochemistry (Boukakis, Patrinou-Georgoula, Lekarakou, Valavanis, Guialis, 2010). HNRNPA1 knockdown inhibited cell viability and colony formation of lung cancer cells and arrested cells in the G0/G1 phase (Liu, Zhou, Lou, Zhong, 2016).

References

Boukakis G, Patrinou-Georgoula M, Lekarakou M, Valavanis C, Guialis A. Deregulated expression of hnRNP A/B proteins in human non-small cell lung cancer: parallel assessment of protein and mRNA levels in paired tumour/non-tumour tissues. BMC Cancer. 2010 Aug 17;10:434

Cammas A, Pileur F, Bonnal S, Lewis SM, Lévêque N, Holcik M, Vagner S. Cytoplasmic relocalization of heterogeneous nuclear ribonucleoprotein A1 controls translation initiation of specific mRNAs. Mol Biol Cell. 2007 Dec;18(12):5048-59

Campillos M, Lamas JR, García MA, Bullido MJ, Valdivieso F, Vázquez J. Specific interaction of heterogeneous nuclear ribonucleoprotein A1 with the -219T allelic form modulates APOE promoter activity. Nucleic Acids Res. 2003 Jun 15;31(12):3063-70

Chen H, Hewison M, Hu B, Adams JS. Heterogeneous nuclear ribonucleoprotein (hnRNP) binding to hormone response elements: a cause of vitamin D resistance. Proc Natl Acad Sci U S A. 2003 May 13;100(10):6109-14

Chen Y, Liu J, Wang W, Xiang L, Wang J, Liu S, Zhou H, Guo Z. High expression of hnRNPA1 promotes cell invasion by inducing EMT in gastric cancer Oncol Rep 2018 Apr;39(4):1693-1701

Cheunim T, Zhang J, Milligan SG, McPhillips MG, Graham SV. The alternative splicing factor hnRNP A1 is up-regulated during virus-infected epithelial cell differentiation and binds the human papillomavirus type 16 late regulatory element Virus Res 2008 Feb;131(2):189-98

David CJ, Chen M, Assanah M, Canoll P, Manley JL. HnRNP proteins controlled by c-Myc deregulate pyruvate kinase mRNA splicing in cancer Nature 2010 Jan 21;463(7279):364-8

Dreyfuss G, Swanson MS, Piñol-Roma S. Heterogeneous nuclear ribonucleoprotein particles and the pathway of mRNA formation Trends Biochem Sci 1988 Mar;13(3):86-91

Fujiya M, Konishi H, Mohamed Kamel MK, Ueno N, Inaba Y, Moriichi K, Tanabe H, Ikuta K, Ohtake T, Kohgo Y. microRNA-18a induces apoptosis in colon cancer cells via the autophagolysosomal degradation of oncogenic heterogeneous nuclear ribonucleoprotein A1 Oncogene 2014 Oct 2;33(40):4847-56

Giannakis M, Mu XJ, Shukla SA, Qian ZR, Cohen O, Nishihara R, Bahl S, Cao Y, Amin-Mansour A, Yamauchi M, Sukawa Y, Stewart C, Rosenberg M, Mima K, Inamura K, Nosho K, Nowak JA, Lawrence MS, Giovannucci EL, Chan AT, Ng K, Meyerhardt JA, Van Allen EM, Getz G, Gabriel SB, Lander ES, Wu CJ, Fuchs CS, Ogino S, Garraway LA. Genomic Correlates of Immune-Cell Infiltrates in Colorectal Carcinoma Cell Rep 2016 Apr 26;15(4):857-865

Goina E, Skoko N, Pagani F. Binding of DAZAP1 and hnRNPA1/A2 to an exonic splicing silencer in a natural BRCA1 exon 18 mutant Mol Cell Biol 2008 Jun;28(11):3850-60

Guil S, Cáceres JF. The multifunctional RNA-binding protein hnRNP A1 is required for processing of miR-18a Nat Struct Mol Biol 2007 Jul;14(7):591-6

Han SP, Tang YH, Smith R. Functional diversity of the hnRNPs: past, present and perspectives Biochem J 2010 Sep 15;430(3):379-92

Hay DC, Kemp GD, Dargemont C, Hay RT. Interaction between hnRNPA1 and IkappaBalpha is required for maximal activation of NF-kappaB-dependent transcription Mol Cell Biol 2001 May;21(10):3482-90

Honda H, Hamasaki H, Wakamiya T, Koyama S, Suzuki SO, Fujii N, Iwaki T. Loss of hnRNPA1 in ALS spinal cord motor neurons with TDP-43-positive inclusions Neuropathology 2015 Feb;35(1):37-43

Hutchison S, LeBel C, Blanchette M, Chabot B. Distinct sets of adjacent heterogeneous nuclear ribonucleoprotein (hnRNP) A1/A2 binding sites control 5' splice site selection in the hnRNP A1 mRNA precursor J Biol Chem 2002 Aug 16;277(33):29745-52

Izumi R, Warita H, Niihori T, Takahashi T, Tateyama M, Suzuki N, Nishiyama A, Shirota M, Funayama R, Nakayama K, Mitsuhashi S, Nishino I, Aoki Y, Aoki M. Isolated inclusion body myopathy caused by a multisystem proteinopathy-linked hnRNPA1 mutation Neurol Genet 2015 Sep 24;1(3):e23

Jønson L, Vikesaa J, Krogh A, Nielsen LK, Hansen Tv, Borup R, Johnsen AH, Christiansen J, Nielsen FC. Molecular composition of IMP1 ribonucleoprotein granules Mol Cell Proteomics 2007 May;6(5):798-811

Jean-Philippe J, Paz S, Caputi M. hnRNP A1: the Swiss army knife of gene expression Int J Mol Sci 2013 Sep 16;14(9):18999-9024

Kim HJ, Kim NC, Wang YD, Scarborough EA, Moore J, Diaz Z, MacLea KS, Freibaum B, Li S, Molliex A, Kanagaraj AP, Carter R, Boylan KB, Wojtas AM, Rademakers R, Pinkus JL, Greenberg SA, Trojanowski JQ, Traynor BJ, Smith BN, Topp S, Gkazi AS, Miller J, Shaw CE, Kottlors M, Kirschner J, Pestronk A, Li YR, Ford AF, Gitler AD, Benatar M, King OD, Kimonis VE, Ross ED, Weihl CC, Shorter J, Taylor JP. Mutations in prion-like domains in hnRNPA2B1 and hnRNPA1 cause multisystem proteinopathy and ALS Nature 2013 Mar 28;495(7442):467-73

Kim YJ, Kim BR, Ryu JS, Lee GO, Kim HR, Choi KH, Ryu JW, Na KS, Park MC, So HS, Cho JH, Park DS. HNRNPA1, a Splicing Regulator, Is an Effective Target Protein for Cervical Cancer Detection: Comparison With Conventional Tumor Markers Int J Gynecol Cancer 2017 Feb;27(2):326-331

Lau JS, Baumeister P, Kim E, Roy B, Hsieh TY, Lai M, Lee AS. Heterogeneous nuclear ribonucleoproteins as regulators of gene expression through interactions with the human thymidine kinase promoter J Cell Biochem 2000 Sep 7;79(3):395-406

Liu Q, Shu S, Wang RR, Liu F, Cui B, Guo XN, Lu CX, Li XG, Liu MS, Peng B, Cui LY, Zhang X. Whole-exome

sequencing identifies a missense mutation in hnRNPA1 in a family with flail arm ALS Neurology 2016 Oct 25;87(17):1763-1769

Liu X, Zhou Y, Lou Y, Zhong H. Knockdown of HNRNPA1 inhibits lung adenocarcinoma cell proliferation through cell cycle arrest at G0/G1 phase Gene 2016 Feb 1;576(2 Pt 2):791-7

Loh TJ, Moon H, Cho S, Jang H, Liu YC, Tai H, Jung DW, Williams DR, Kim HR, Shin MG, Liao DJ, Zhou J, Shi W, Zheng X, Shen H. CD44 alternative splicing and hnRNP A1 expression are associated with the metastasis of breast cancer Oncol Rep 2015 Sep;34(3):1231-8

Martínez-Salas E, Piñeiro D, Fernández N. Alternative Mechanisms to Initiate Translation in Eukaryotic mRNAs Comp Funct Genomics 2012;2012:391546

Mendell JT, Sharifi NA, Meyers JL, Martinez-Murillo F, Dietz HC. Nonsense surveillance regulates expression of diverse classes of mammalian transcripts and mutes genomic noise Nat Genet 2004 Oct;36(10):1073-8

Michlewski G, Cáceres JF. Antagonistic role of hnRNP A1 and KSRP in the regulation of let-7a biogenesis Nat Struct Mol Biol 2010 Aug;17(8):1011-8

Mili S, Shu HJ, Zhao Y, Piñol-Roma S. Distinct RNP complexes of shuttling hnRNP proteins with pre-mRNA and mRNA: candidate intermediates in formation and export of mRNA Mol Cell Biol 2001 Nov;21(21):7307-19

Otsuka K, Yamamoto Y, Ochiya T. Regulatory role of resveratrol, a microRNA-controlling compound, in HNRNPA1 expression, which is associated with poor prognosis in breast cancer Oncotarget 2018 May 15;9(37):24718-24730

Piñol-Roma S, Dreyfuss G. Shuttling of pre-mRNA binding proteins between nucleus and cytoplasm Nature 1992 Feb

20;355(6362):730-2

Roy R, Durie D, Li H, Liu BQ, Skehel JM, Mauri F, Cuorvo

LV, Barbareschi M, Guo L, Holcik M, Seckl MJ, Pardo OE. hnRNPA1 couples nuclear export and translation of specific mRNAs downstream of FGF-2/S6K2 signalling Nucleic Acids Res 2014 Nov 10;42(20):12483-97

Singh AK, Lakhotia SC. The hnRNP A1 homolog Hrp36 is essential for normal development, female fecundity, omega speckle formation and stress tolerance in Drosophila melanogaster J Biosci 2012 Sep;37(4):659-78

Talukdar I, Sen S, Urbano R, Thompson J, Yates JR 3rd, Webster NJ. hnRNP A1 and hnRNP F modulate the alternative splicing of exon 11 of the insulin receptor gene PLoS One 2011;6(11):e27869

Teng Y, Manavalan TT, Hu C, Medjakovic S, Jungbauer A, Klinge CM. Endocrine disruptors fludioxonil and fenhexamid stimulate miR-21 expression in breast cancer cells Toxicol Sci 2013 Jan;131(1):71-83

Ushigome M, Ubagai T, Fukuda H, Tsuchiya N, Sugimura T, Takatsuka J, Nakagama H. Up-regulation of hnRNP A1 gene in sporadic human colorectal cancers Int J Oncol 2005 Mar;26(3):635-40

Xia H. Regulation of gamma-fibrinogen chain expression by heterogeneous nuclear ribonucleoprotein A1 J Biol Chem 2005 Apr 1;280(13):13171-8

Yu Z, Tang PL, Wang J, Bao S, Shieh JT, Leung AW, Zhang Z, Gao F, Wong SY, Hui AL, Gao Y, Dung N, Zhang ZG, Fan Y, Zhou X, Zhang Y, Wong DS, Sham PC, Azhar A, Kwok PY, Tam PP, Lian Q, Cheah KS, Wang B, Song YQ. Mutations in Hnrnpa1 cause congenital heart defects JCI Insight 2018 Jan 25;3(2)

Zhang QS, Manche L, Xu RM, Krainer AR. hnRNP A1 associates with telomere ends and stimulates telomerase activity RNA 2006 Jun;12(6):1116-28

Zhou ZJ, Dai Z, Zhou SL, Fu XT, Zhao YM, Shi YH, Zhou J, Fan J. Overexpression of HnRNP A1 promotes tumor invasion through regulating CD44v6 and indicates poor prognosis for hepatocellular carcinoma Int J Cancer 2013 Mar 1;132(5):1080-9

This article should be referenced as such:

Erdem M, Özgül I, Erson-Bensan AE. HNRNPA1 (Heterogeneous Nuclear Ribonucleoprotein A1). Atlas Genet Cytogenet Oncol Haematol. 2019; 23(6):137-142.