

Title: Targeted genomic CRISPR-Cas9 screen identifies MAP4K4 as essential for glioblastoma invasion

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Supplementary Table 1: Genes targeted by sgRNAs disenriched from the library

Symbol	GeneInfo	Function
RAB4B	RAB4B, member RAS oncogene family	molecular_function GTP binding
PTPN20B	protein tyrosine phosphatase, non-receptor type 20B	protein tyrosine phosphatase activity
NEDD8-MDP1	NEDD8-MDP1 readthrough	None
FDX1L	ferredoxin 1-like	electron carrier activity metal ion binding 2 iron, 2 sulfur cluster binding
GOSR2	golgi SNAP receptor complex member 2	transporter activity
CDY2A	chromodomain protein, Y-linked, 2A	None
STX16	syntaxin 16	SNAP receptor activity protein binding
SLC25A10	solute carrier family 25 (mitochondrial carrier; dicarboxylate transporter), member 10	dicarboxylic acid transmembrane transporter activity protein binding
VKORC1	vitamin K epoxide reductase complex, subunit 1	vitamin-K-epoxide reductase (warfarin-sensitive) activity quinone binding
UGT1A8	UDP glucuronosyltransferase 1 family, polypeptide A8	retinoic acid binding enzyme inhibitor activity steroid binding fatty acid binding drug binding glucuronosyltransferase activity enzyme binding protein homodimerization activity protein homodimerization activity protein heterodimerization activity protein heterodimerization activity
MRPL30	mitochondrial ribosomal protein L30	None
CDY1	chromodomain protein, Y-linked, 1	None
HOGA1	4-hydroxy-2-oxoglutarate aldolase 1	4-hydroxy-2-oxoglutarate aldolase activity 4-hydroxy-2-oxoglutarate aldolase activity protein homodimerization activity
DDX19B	DEAD (Asp-Glu-Ala-Asp) box polypeptide 19B	RNA binding helicase activity ATP binding
SQRDL	sulfide quinone reductase-like (yeast)	sulfide:quinone oxidoreductase activity
CCL3L1	chemokine (C-C motif) ligand 3-like 1	None
GATC	glutamyl-tRNA(Gln) amidotransferase, subunit C	ATP binding glutamyl-tRNA synthase (glutamine-hydrolyzing) activity
PRY2	PTPN13-like, Y-linked 2	None
CSNK2B	casein kinase 2, beta polypeptide	protein serine/threonine kinase activity receptor binding protein binding transcription factor binding protein kinase regulator activity protein domain specific binding identical protein binding metal ion binding
PPAN	peter pan homolog (Drosophila)	poly(A) RNA binding
TMX2	thioredoxin-related transmembrane protein 2	molecular_function
BLOC1S5	biogenesis of lysosomal organelles complex-1, subunit 5, muted	protein binding
ARL17A	ADP-ribosylation factor-like 17A	None
TIMM23	translocase of inner mitochondrial membrane 23 homolog (yeast)	protein binding P-P-bond-hydrolysis-driven protein transmembrane transporter activity

KPNB1	karyopherin (importin) beta 1	protein binding nuclear localization sequence binding zinc ion binding Ran GTPase binding protein transporter activity enzyme binding protein domain specific binding poly(A) RNA binding
TRAPPC5	trafficking protein particle complex 5	None
PSMA2	proteasome (prosome, macropain) subunit, alpha type, 2	threonine-type endopeptidase activity protein binding
SNRPD2	small nuclear ribonucleoprotein D2 polypeptide 16.5kDa	protein binding poly(A) RNA binding
TMEM141	transmembrane protein 141	None
HSPA5	heat shock 70kDa protein 5 (glucose-regulated protein, 78kDa)	glycoprotein binding calcium ion binding protein binding ATP binding ATPase activity enzyme binding protein domain specific binding ubiquitin protein ligase binding ribosome binding unfolded protein binding chaperone binding misfolded protein binding
AMY1A	amylase, alpha 1A (salivary)	None
BCKDHA	branched chain keto acid dehydrogenase E1, alpha polypeptide	alpha-ketoacid dehydrogenase activity 3-methyl-2-oxobutanoate dehydrogenase (2-methylpropanoyl-transferring) activity protein binding carboxy-lyase activity metal ion binding
NDUFC2	NADH dehydrogenase (ubiquinone) 1, subcomplex unknown, 2, 14.5kDa	NADH dehydrogenase (ubiquinone) activity
PTGR2	prostaglandin reductase 2	13-prostaglandin reductase activity 15-oxoprostaglandin 13-oxidase activity
HMGCS1	3-hydroxy-3-methylglutaryl-CoA synthase 1 (soluble)	hydroxymethylglutaryl-CoA synthase activity drug binding isomerase activity protein homodimerization activity organic acid binding
IFNAR2	interferon (alpha, beta and omega) receptor 2	type I interferon receptor activity protein binding protein kinase binding type I interferon binding
RNASET2	ribonuclease T2	RNA binding ribonuclease activity ribonuclease T2 activity
DMPK	dystrophia myotonica-protein kinase	protein serine/threonine kinase activity protein binding ATP binding myosin phosphatase regulator activity heat shock protein binding metal ion binding
COG8	component of oligomeric golgi complex 8	None
BCO2	beta-carotene oxygenase 2	oxidoreductase activity, acting on single donors with incorporation of molecular oxygen, incorporation of two atoms of oxygen metal ion binding
NAA25	N(alpha)-acetyltransferase 25, NatB auxiliary subunit	None
DDT	D-dopachrome tautomerase	dopachrome isomerase activity D-dopachrome decarboxylase activity
GSTT2	glutathione S-transferase theta 2	glutathione transferase activity
CSNK1G1	casein kinase 1, gamma 1	protein serine/threonine kinase activity ATP binding
GSK3A	glycogen synthase kinase 3 alpha	protein serine/threonine kinase activity protein binding ATP binding protein kinase A catalytic subunit binding tau-protein kinase activity
NHP2L1	NHP2 non-histone chromosome protein 2-like 1 (S. cerevisiae)	RNA binding protein binding snoRNA binding poly(A) RNA binding
HMGCR	3-hydroxy-3-methylglutaryl-CoA reductase	hydroxymethylglutaryl-CoA reductase (NADPH) activity protein binding hydroxymethylglutaryl-CoA

		reductase activity protein homodimerization activity coenzyme binding NADPH binding
TNNI3K	TNNI3 interacting kinase	protein kinase activity protein serine/threonine kinase activity protein binding ATP binding protein C-terminus binding troponin I binding metal ion binding
PPP3R1	protein phosphatase 3, regulatory subunit B, alpha	calcium-dependent protein serine/threonine phosphatase activity calcium ion binding protein binding calmodulin binding protein domain specific binding
PPP1CB	protein phosphatase 1, catalytic subunit, beta isozyme	protein binding phosphatase activity myosin phosphatase activity protein kinase binding metal ion binding myosin-light-chain-phosphatase activity
AARS	alanyl-tRNA synthetase	tRNA binding aminoacyl-tRNA editing activity alanine-tRNA ligase activity ATP binding zinc ion binding amino acid binding
S100A7	S100 calcium binding protein A7	calcium ion binding protein binding zinc ion binding zinc ion binding RAGE receptor binding
GBF1	golgi brefeldin A resistant guanine nucleotide exchange factor 1	ARF guanyl-nucleotide exchange factor activity protein binding
EIF4A3	eukaryotic translation initiation factor 4A3	mRNA binding ATP-dependent RNA helicase activity protein binding ATP binding poly(A) binding poly(A) RNA binding
SF3B1	splicing factor 3b, subunit 1, 155kDa	chromatin binding protein binding poly(A) RNA binding
MTHFS	5,10-methenyltetrahydrofolate synthetase (5-formyltetrahydrofolate cyclo-ligase)	ATP binding folic acid binding 5-formyltetrahydrofolate cyclo-ligase activity 5-formyltetrahydrofolate cyclo-ligase activity
SDHAF2	succinate dehydrogenase complex assembly factor 2	protein binding
BANF1	barrier to autointegration factor 1	DNA binding protein binding
UBC	ubiquitin C	protease binding protein binding poly(A) RNA binding
RNGTT	RNA guanylyltransferase and 5'-phosphatase	mRNA guanylyltransferase activity polynucleotide 5'-phosphatase activity protein tyrosine phosphatase activity GTP binding protein tyrosine/serine/threonine phosphatase activity RNA guanylyltransferase activity triphosphatase activity
PLK1	polo-like kinase 1	protein kinase activity protein serine/threonine kinase activity protein serine/threonine kinase activity protein serine/threonine kinase activity protein binding ATP binding microtubule binding anaphase-promoting complex binding kinase activity protein kinase binding
PPP1R10	protein phosphatase 1, regulatory subunit 10	DNA binding protein phosphatase inhibitor activity poly(A) RNA binding metal ion binding
CDC7	cell division cycle 7	protein kinase activity protein serine/threonine kinase activity protein binding ATP binding kinase activity metal ion binding
TXNRD1	thioredoxin reductase 1	thioredoxin-disulfide reductase activity protein binding electron carrier activity protein disulfide oxidoreductase activity flavin adenine dinucleotide binding NADP binding

MTAP	methylthioadenosine phosphorylase	phosphorylase activity S-methyl-5-thioadenosine phosphorylase activity
PTPN1	protein tyrosine phosphatase, non-receptor type 1	protein tyrosine phosphatase activity protein tyrosine phosphatase activity insulin receptor binding protein binding zinc ion binding enzyme binding protein kinase binding receptor tyrosine kinase binding poly(A) RNA binding ephrin receptor binding
SLC25A22	solute carrier family 25 (mitochondrial carrier: glutamate), member 22	L-glutamate transmembrane transporter activity symporter activity
SERPINB2	serpin peptidase inhibitor, clade B (ovalbumin), member 2	serine-type endopeptidase inhibitor activity
SARS	seryl-tRNA synthetase	RNA binding serine-tRNA ligase activity ATP binding
PPIA	peptidylprolyl isomerase A (cyclophilin A)	peptidyl-prolyl cis-trans isomerase activity protein binding peptide binding poly(A) RNA binding virion binding unfolded protein binding
LSM6	LSM6 homolog, U6 small nuclear RNA associated (<i>S. cerevisiae</i>)	protein binding poly(A) RNA binding
HGS	hepatocyte growth factor-regulated tyrosine kinase substrate	protein binding protein domain specific binding metal ion binding
PTPN23	protein tyrosine phosphatase, non-receptor type 23	protein tyrosine phosphatase activity protein binding
SNRPD3	small nuclear ribonucleoprotein D3 polypeptide 18kDa	protein binding enzyme binding poly(A) RNA binding histone pre-mRNA DCP binding
CKS1B	CDC28 protein kinase regulatory subunit 1B	protein binding cyclin-dependent protein serine/threonine kinase regulator activity
VPS28	vacuolar protein sorting 28 homolog (<i>S. cerevisiae</i>)	protein binding
XRN2	5'-3' exoribonuclease 2	nuclease activity 5'-3' exoribonuclease activity zinc ion binding 5'-3' exonuclease activity poly(A) RNA binding
DCTN5	dynactin 5 (p25)	None
AURKA	aurora kinase A	protein kinase activity protein serine/threonine kinase activity protein serine/threonine/tyrosine kinase activity protein binding ATP binding protein kinase binding ubiquitin protein ligase binding
NUP188	nucleoporin 188kDa	None
THG1L	tRNA-histidine guanylyltransferase 1-like (<i>S. cerevisiae</i>)	tRNA binding magnesium ion binding ATP binding GTP binding tRNA guanylyltransferase activity tRNA guanylyltransferase activity identical protein binding
RAD51C	RAD51 paralog C	four-way junction DNA binding DNA binding protein binding ATP binding DNA-dependent ATPase activity crossover junction endodeoxyribonuclease activity
RAPGEF1	Rap guanine nucleotide exchange factor (GEF) 1	protein binding Rap guanyl-nucleotide exchange factor activity Rap guanyl-nucleotide exchange factor activity SH3 domain binding
DCTN6	dynactin 6	dynein binding
TOMM20	translocase of outer mitochondrial membrane 20 homolog (yeast)	protein binding P-P-bond-hydrolysis-driven protein transmembrane transporter activity unfolded protein binding

VCX3A	variable charge, X-linked 3A	None
FCF1	FCF1 rRNA-processing protein	poly(A) RNA binding
DYNLRB1	dynein, light chain, roadblock-type 1	microtubule motor activity identical protein binding
ACTR10	actin-related protein 10 homolog (S. cerevisiae)	None
TMED2	transmembrane emp24 domain trafficking protein 2	protein binding
ARHGAP8	Rho GTPase activating protein 8	Rho GTPase activator activity protein binding
PTPN11	protein tyrosine phosphatase, non-receptor type 11	phosphoprotein phosphatase activity protein tyrosine phosphatase activity protein tyrosine phosphatase activity non-membrane spanning protein tyrosine phosphatase activity non-membrane spanning protein tyrosine phosphatase activity SH3/SH2 adaptor activity insulin receptor binding protein binding protein domain specific binding receptor tyrosine kinase binding D1 dopamine receptor binding phospholipase binding insulin receptor substrate binding peptide hormone receptor binding
PPP1R2	protein phosphatase 1, regulatory (inhibitor) subunit 2	protein serine/threonine phosphatase inhibitor activity protein binding
TPSB2	trypsin beta 2 (gene/pseudogene)	serine-type endopeptidase activity serine-type peptidase activity
DHX37	DEAH (Asp-Glu-Ala-His) box polypeptide 37	nucleic acid binding helicase activity ATP binding
ALG1	ALG1, chitobiosyldiphosphodolichol beta-mannosyltransferase	mannosyltransferase activity chitobiosyldiphosphodolichol beta-mannosyltransferase activity
GOLGA6L1	golgin A6 family-like 1	None
S100G	S100 calcium binding protein G	vitamin D binding calcium ion binding

Supplementary Table 2: Genes targeted by sgRNAs enriched in the non-invasive population

Symbol	GeneInfo	Function
MAP4K4	mitogen-activated protein kinase kinase kinase 4	protein serine/threonine kinase activity small GTPase regulator activity protein binding ATP binding
AARS	alanyl-tRNA synthetase	tRNA binding aminoacyl-tRNA editing activity alanine-tRNA ligase activity ATP binding zinc ion binding amino acid binding
NARS	asparaginyl-tRNA synthetase	nucleic acid binding asparagine-tRNA ligase activity ATP binding
ACTR2	ARP2 actin-related protein 2 homolog (yeast)	actin binding ATP binding
ABCE1	ATP-binding cassette, sub-family E (OABP), member 1	ATP binding ribonuclease inhibitor activity ATPase activity iron-sulfur cluster binding
TAOK1	TAO kinase 1	protein kinase activity protein serine/threonine kinase activity protein serine/threonine kinase activity protein binding ATP binding kinase activity transferase activity
GAPDH	glyceraldehyde-3-phosphate dehydrogenase	glyceraldehyde-3-phosphate dehydrogenase (NAD+) (phosphorylating) activity glyceraldehyde-3-phosphate

		dehydrogenase (NAD+) (phosphorylating) activity protein binding microtubule binding peptidyl-cysteine S-nitrosylase activity identical protein binding NADP binding NAD binding
GGPS1	geranylgeranyl diphosphate synthase 1	dimethylallyltranstransferase activity farnesyltranstransferase activity geranyltranstransferase activity metal ion binding
CKS1B	CDC28 protein kinase regulatory subunit 1B	protein binding cyclin-dependent protein serine/threonine kinase regulator activity
SEH1L	SEH1-like (<i>S. cerevisiae</i>)	None
CDK9	cyclin-dependent kinase 9	DNA binding chromatin binding protein kinase activity cyclin-dependent protein serine/threonine kinase activity protein binding ATP binding RNA polymerase II carboxy-terminal domain kinase activity snRNA binding transcription regulatory region DNA binding
EEF2	eukaryotic translation elongation factor 2	translation elongation factor activity GTPase activity GTP binding translation activator activity protein kinase binding poly(A) RNA binding
CDK1	cyclin-dependent kinase 1	protein kinase activity protein serine/threonine kinase activity cyclin-dependent protein serine/threonine kinase activity cyclin-dependent protein serine/threonine kinase activity protein binding ATP binding RNA polymerase II carboxy-terminal domain kinase activity cyclin binding Hsp70 protein binding histone kinase activity
RBMXL1	RNA binding motif protein, X-linked-like 1	nucleotide binding RNA binding
DHX30	DEAH (Asp-Glu-Ala-His) box helicase 30	chromatin binding double-stranded RNA binding protein binding ATP binding ATP-dependent helicase activity poly(A) RNA binding
NGLY1	N-glycanase 1	peptide-N4-(N-acetyl-beta-glucosaminyl)asparagine amidase activity protein binding metal ion binding
CAP1	CAP, adenylate cyclase-associated protein 1 (yeast)	actin binding
HARS	histidyl-tRNA synthetase	histidine-tRNA ligase activity ATP binding
PPP1R8	protein phosphatase 1, regulatory subunit 8	DNA binding RNA binding endonuclease activity protein serine/threonine phosphatase inhibitor activity protein binding protein phosphatase type 1 regulator activity ribonuclease E activity
EFTUD1	elongation factor Tu GTP binding domain containing 1	translation elongation factor activity GTPase activity GTP binding ribosome binding
TRAPPC3	trafficking protein particle complex 3	protein binding
PDGFRA	platelet-derived growth factor receptor, alpha polypeptide	transmembrane receptor protein tyrosine kinase activity platelet-derived growth factor alpha-receptor activity platelet-derived growth factor alpha-receptor activity vascular endothelial growth factor-activated receptor activity platelet-derived growth factor receptor binding protein binding ATP binding vascular endothelial growth factor binding protein homodimerization activity platelet-derived growth factor binding platelet-derived growth factor binding
PFN1	profilin 1	adenyl-nucleotide exchange factor activity actin binding receptor binding protein binding phosphatidylinositol-4,5-bisphosphate binding Rho GTPase binding poly(A) RNA binding proline-rich region binding

FCGR1B	Fc fragment of IgG, high affinity Ib, receptor (CD64)	immunoglobulin receptor activity IgG binding
MRPL43	mitochondrial ribosomal protein L43	structural constituent of ribosome poly(A) RNA binding
XPO1	exportin 1	RNA binding transporter activity nucleocytoplasmic transporter activity protein binding Ran GTPase binding protein transporter activity protein domain specific binding
ABCF1	ATP-binding cassette, sub-family F (GCN20), member 1	protein binding ATP binding ATP binding translation factor activity, nucleic acid binding translation activator activity ATPase activity ribosome binding poly(A) RNA binding
BTAF1	BTAF1 RNA polymerase II, B-TFIID transcription factor-associated, 170kDa	DNA binding sequence-specific DNA binding transcription factor activity helicase activity ATP binding
YARS	tyrosyl-tRNA synthetase	tRNA binding tyrosine-tRNA ligase activity signal transducer activity interleukin-8 receptor binding ATP binding poly(A) RNA binding
NSF	N-ethylmaleimide-sensitive factor	protein binding ATP binding syntaxin-1 binding protein kinase binding PDZ domain binding protein complex binding ATPase activity, coupled metal ion binding
NHP2L1	NHP2 non-histone chromosome protein 2-like 1 (<i>S. cerevisiae</i>)	RNA binding protein binding snoRNA binding poly(A) RNA binding
ARPC3	actin related protein 2/3 complex, subunit 3, 21kDa	actin binding structural constituent of cytoskeleton protein binding
LSM6	LSM6 homolog, U6 small nuclear RNA associated (<i>S. cerevisiae</i>)	protein binding poly(A) RNA binding