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**Lamont**

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(54) **IDENTIFICATION OF GENETIC VARIANTS**

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(73) Assignee: **RANDOX LABORATORIES LTD.**  
(GB)

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patent is extended or adjusted under 35  
U.S.C. 154(b) by 0 days.

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(22) Filed: **Jul. 3, 2014**

(65) **Prior Publication Data**

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24, 2012, now abandoned.

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25, 2011.

(51) **Int. Cl.**

<b><i>C12Q 1/68</i></b>	(2006.01)
<b><i>C12P 19/34</i></b>	(2006.01)
<b><i>A61K 31/404</i></b>	(2006.01)
<b><i>A61K 31/4439</i></b>	(2006.01)
<b><i>A61K 31/517</i></b>	(2006.01)

(52) **U.S. Cl.**

CPC ..... ***C12Q 1/6883*** (2013.01); ***A61K 31/404***  
(2013.01); ***A61K 31/4439*** (2013.01); ***A61K***  
***31/517*** (2013.01); ***C12Q 2600/106*** (2013.01);  
***C12Q 2600/156*** (2013.01)

(58) **Field of Classification Search**

None  
See application file for complete search history.

(56) **References Cited**

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2006/0073506 A1	4/2006	Christians et al.

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Loomis et al; *Annals of Oncology*, vol. 21, p. vi26, 2010.\*  
ss172911331 (dbSNP, NCBI, NLM 2009).

\* cited by examiner

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Eisenschenk

(57) **ABSTRACT**

The present disclosure provides a method for identifying  
whether a subject is more or less likely to be responsive to  
VEGF-based therapy, comprising screening a nucleic acid  
sample obtained from the subject to provide output infor-  
mation which identifies the presence or absence of an allelic  
variant, wherein the presence or absence of an allelic variant  
indicates whether the subject is more or less likely to be  
responsive to VEGF-based therapy.

**21 Claims, 12 Drawing Sheets**

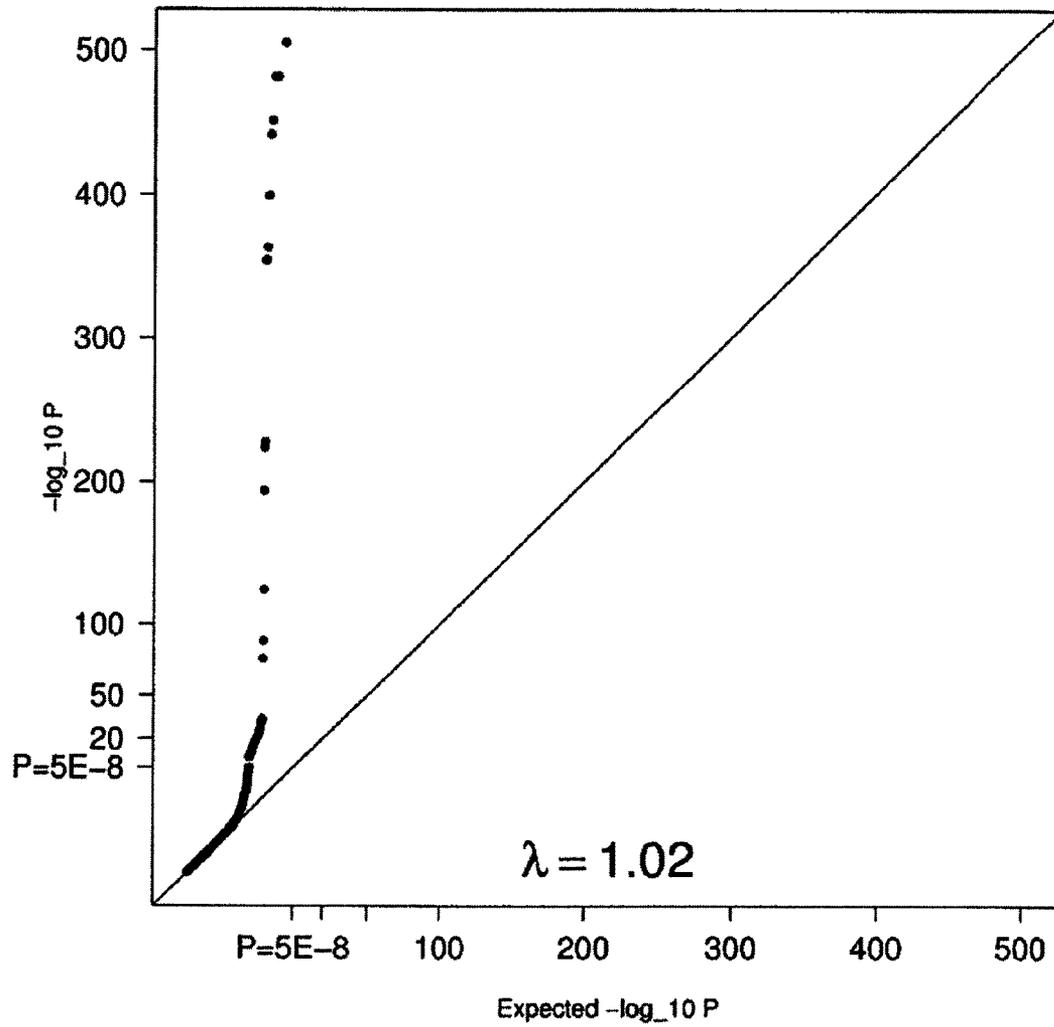


FIGURE 1

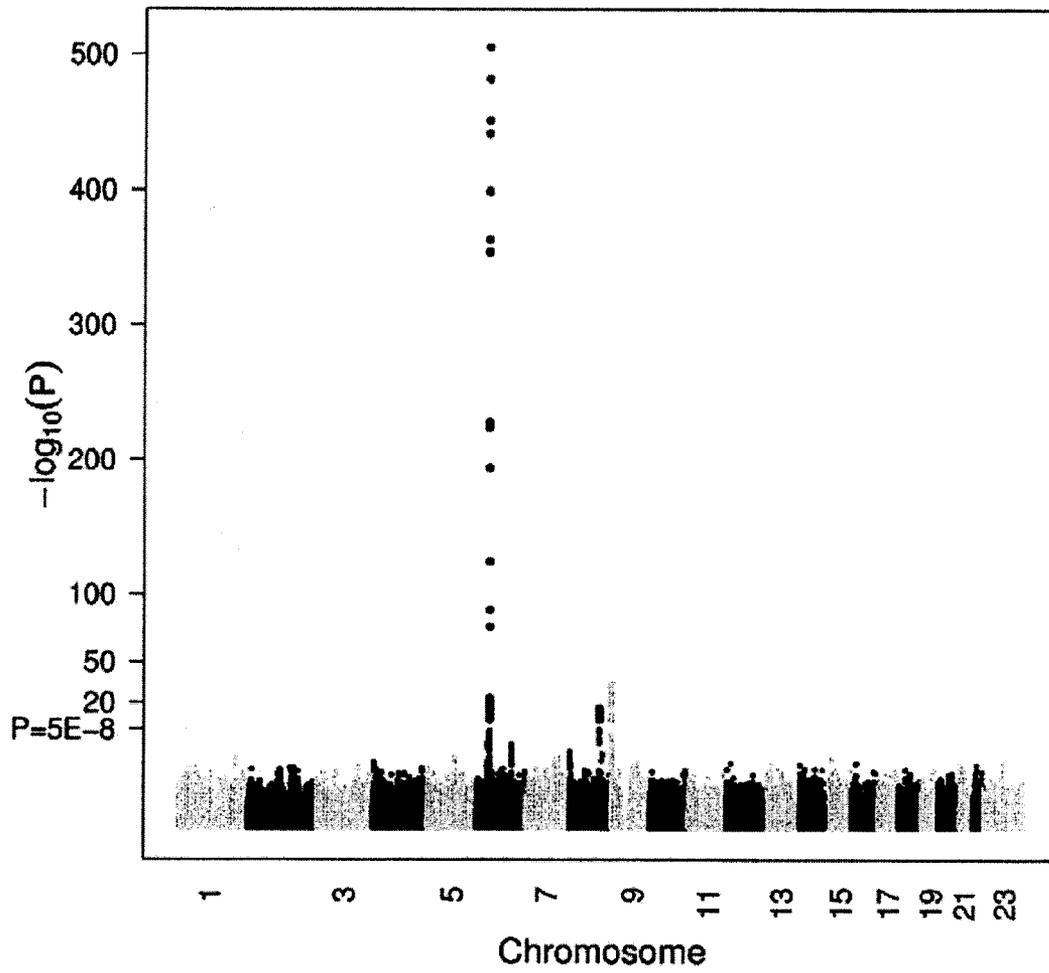


FIGURE 2

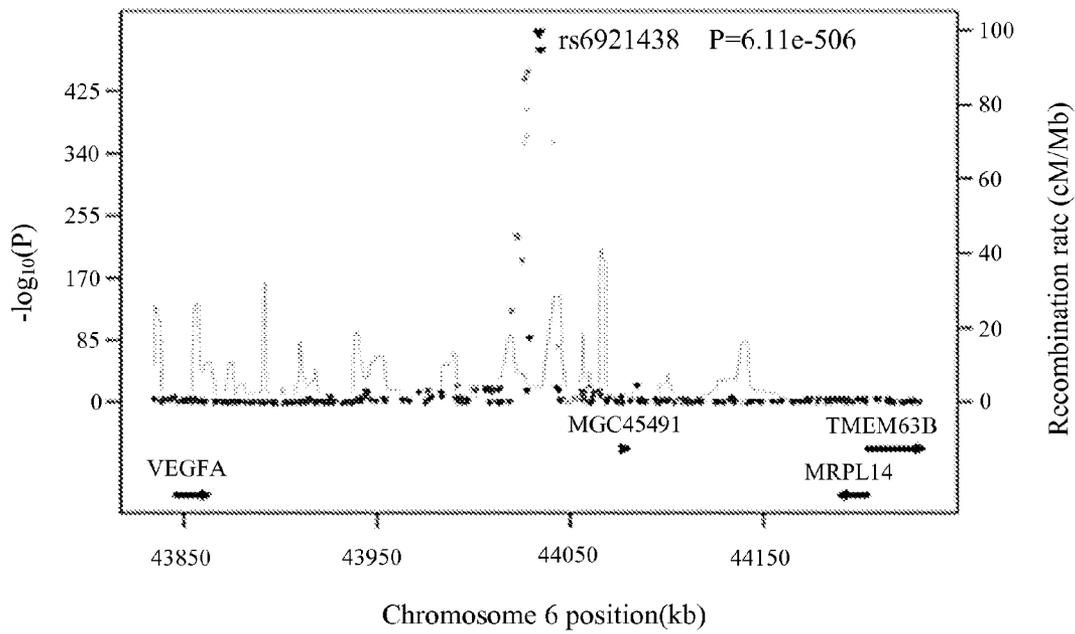


FIG. 3A

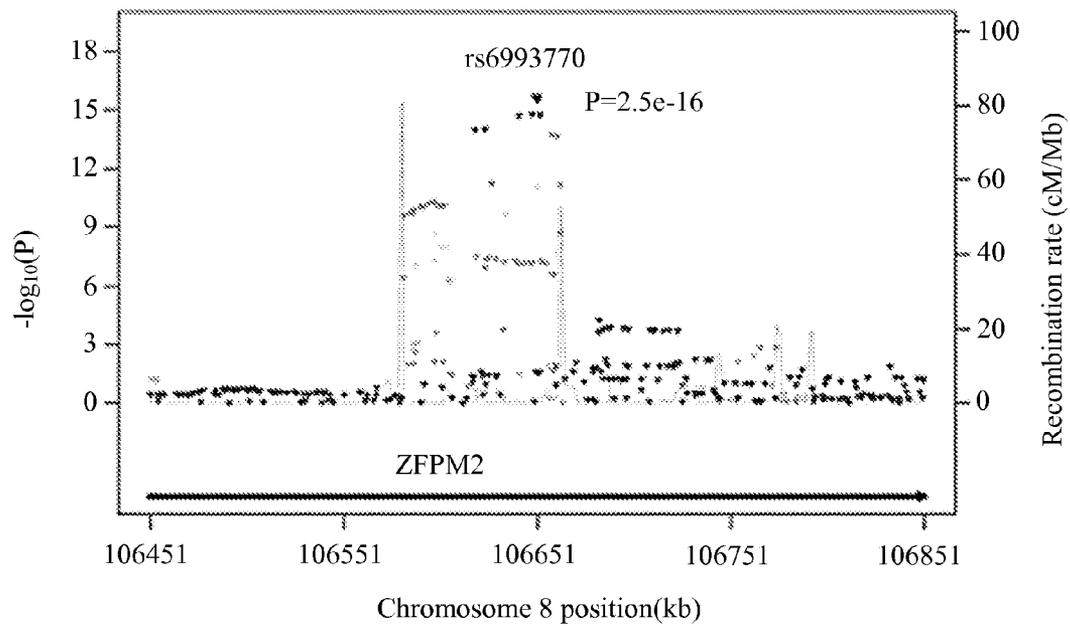


FIG. 3B

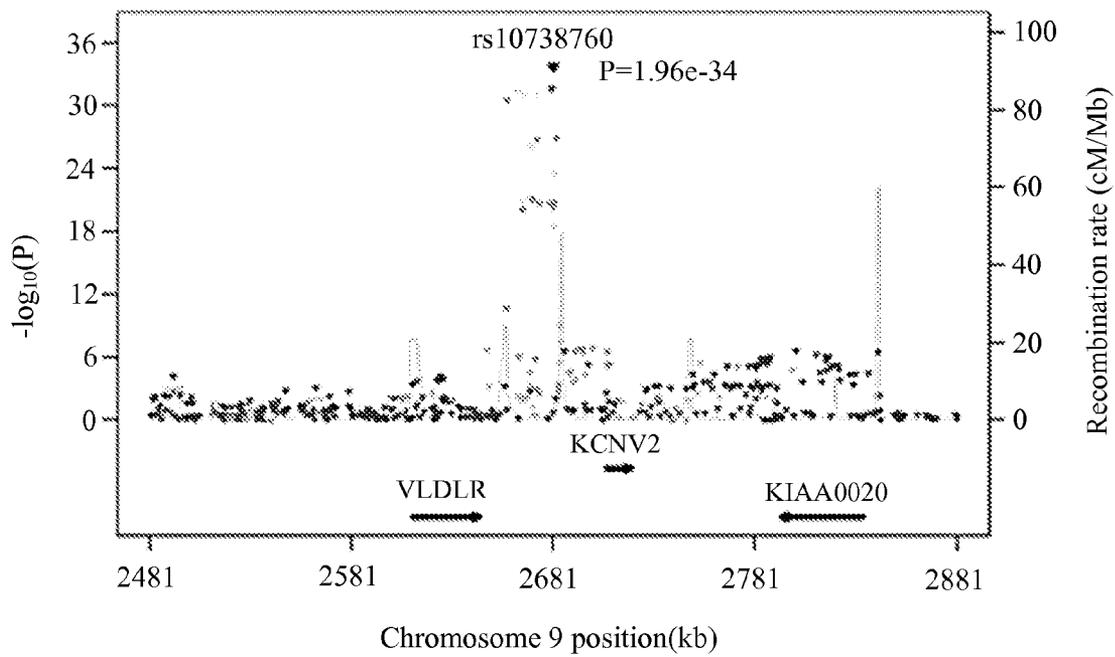
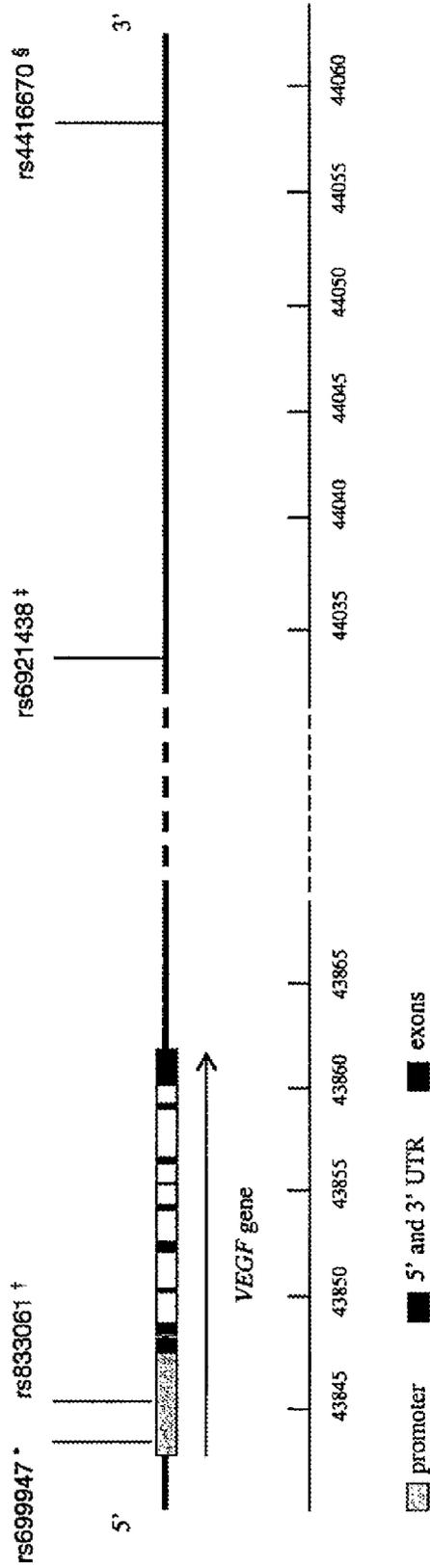
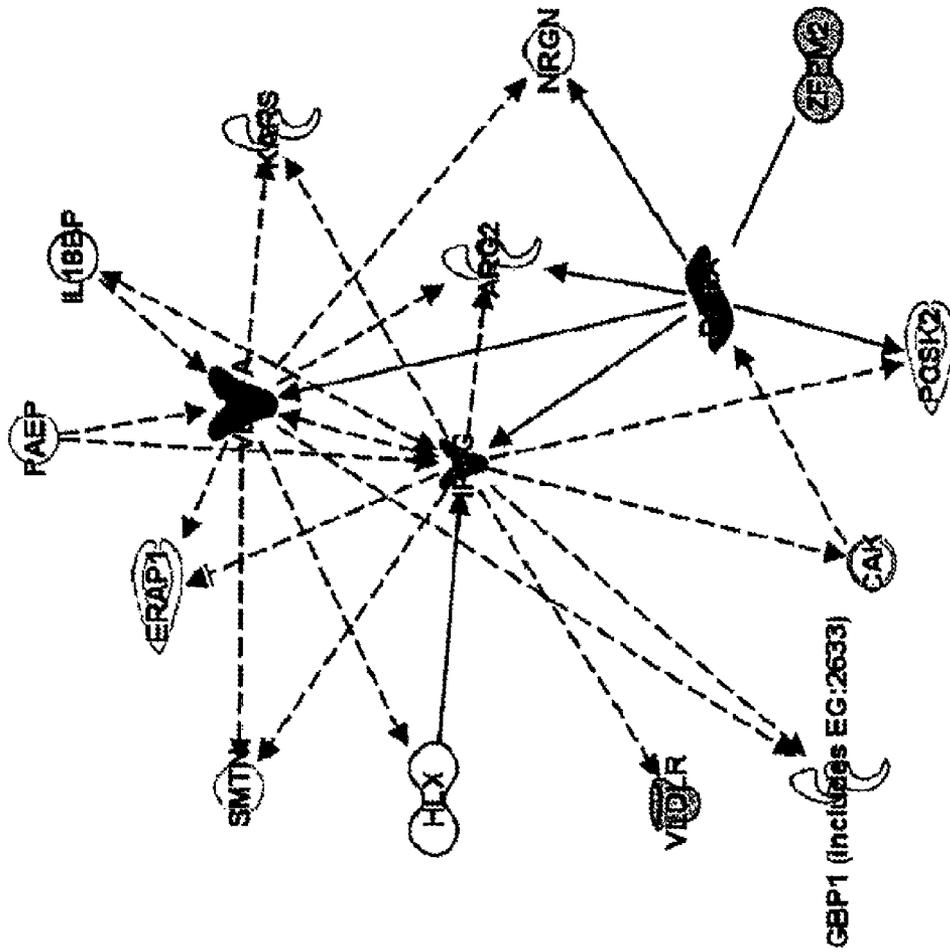


FIG. 3C



\*chr6:43844367,  $p=2.33 \times 10^{-7}$  replicates findings from previous association studies (Table 6)  
†chr6:43845464,  $p=3.05 \times 10^{-7}$ , replicates findings from previous association studies (y Table 6)  
‡ chr6:44033585,  $p=6.11 \times 10^{-508}$ , top SNP, explains 41.2% of the phenotypic variance in the FHS  
§ chr6:44058431,  $p=1.47 \times 10^{-12}$ , associated with serum VEGF levels independently of rs6921438 in conditional GWAS, explains 1.5% of the phenotypic variance in the FHS

FIG. 4



- Complex
  - Y Cytokine/Growth Factor
  - o Enzyme
  - o Ligand-dependent Nuclear Receptor
  - o Peptidase
  - o Transcription Regulator
  - o Transporter
- 
- Direct Interaction
  - - - Indirect Interaction
- 
- Main Gene of Interest
  - o Other focus genes
  - Main nodes

FIG. 5

SNP	Chr	Position	CA	CAF	beta	SE	P	Gene 1	Distance	Gene 2	Distance	Function	O/E ratio	Imputed
rs9921438	6	44033585	G	0.52	0.72	0.01	6.11E-506	MGC45491	42731	MIRPL14	153764	INTERGENIC	0.99	0
rs7767396	6	440335028	G	0.47	-0.71	0.02	1.71E-482	MGC45491	41286	MIRPL14	154321	INTERGENIC	0.99	1
rs4513773	6	44033504	G	0.46	-0.71	0.02	2.08E-482	MGC45491	42812	MIRPL14	155845	INTERGENIC	1.30	0
rs9472159	6	44027673	C	0.51	0.76	0.02	4.30E-452	MGC45491	48643	MIRPL14	161676	INTERGENIC	0.52	1
rs9369434	6	44026385	C	0.53	0.95	0.02	2.15E-442	MGC45491	49931	MIRPL14	162984	INTERGENIC	0.66	1
rs8916314	6	44027140	G	0.38	0.92	0.02	3.13E-400	MGC45491	49176	MIRPL14	162209	INTERGENIC	0.54	1
rs9472158	6	44026875	G	0.38	0.92	0.02	6.22E-400	MGC45491	49441	MIRPL14	162474	INTERGENIC	0.54	1
rs8916540	6	44027394	C	0.40	0.67	0.02	3.60E-364	MGC45491	48922	MIRPL14	161955	INTERGENIC	0.56	1
rs9472173	6	44041234	C	0.47	0.93	0.02	1.16E-355	MGC45491	35082	MIRPL14	148115	INTERGENIC	0.47	1
rs729391	6	44025870	C	0.39	1.05	0.03	7.17E-355	MGC45491	50446	MIRPL14	163479	INTERGENIC	0.36	1
rs7764227	6	44021966	G	0.26	1.32	0.04	1.41E-228	MGC45491	54350	VEGFA	159767	INTERGENIC	0.22	1
rs8369433	6	44023528	C	0.23	1.28	0.04	6.87E-225	MGC45491	53788	VEGFA	160329	INTERGENIC	0.25	1
rs1359617	6	44024870	T	0.11	1.87	0.06	1.56E-194	MGC45491	51446	VEGFA	162671	INTERGENIC	0.18	1
rs8655685	6	44019529	C	0.29	0.83	0.04	3.16E-125	MGC45491	56787	VEGFA	157330	INTERGENIC	0.30	1
rs6458360	6	44028870	T	0.11	1.10	0.05	3.14E-89	MGC45491	47446	MIRPL14	160479	INTERGENIC	0.28	1
rs17209449	6	44043245	C	0.09	-1.20	0.06	1.30E-76	MGC45491	33071	MIRPL14	146104	INTERGENIC	0.24	1
rs10738760	9	2681186	A	0.49	0.28	0.02	1.96E-34	KCNV2	26339	VLDLR	36701	INTERGENIC	0.68	1
rs10757631	9	2680295	G	0.47	-0.26	0.02	2.30E-32	KCNV2	27230	VLDLR	35810	INTERGENIC	0.73	1
rs6475919	9	2662809	T	0.37	-0.24	0.02	3.63E-32	VLDLR	18324	KCNV2	44716	INTERGENIC	0.95	1
rs6475920	9	2663933	A	0.37	-0.24	0.02	3.76E-32	VLDLR	19446	KCNV2	43592	INTERGENIC	0.96	1
rs1020651	9	2666360	G	0.37	-0.23	0.02	8.60E-32	VLDLR	21875	KCNV2	41165	INTERGENIC	1.01	1
rs1020652	9	2667012	T	0.37	-0.23	0.02	8.69E-32	VLDLR	22527	KCNV2	40513	INTERGENIC	1.01	0
rs10738758	9	2672355	G	0.37	-0.23	0.02	9.11E-32	VLDLR	27870	KCNV2	35170	INTERGENIC	0.98	1
rs4741756	9	2658187	C	0.28	-0.25	0.02	2.95E-31	VLDLR	13702	KCNV2	49338	INTERGENIC	0.97	0
rs2375980	9	2682632	G	0.42	-0.25	0.02	1.30E-27	KCNV2	24903	VLDLR	36137	INTERGENIC	0.70	1
rs7856084	9	2672943	C	0.39	-0.22	0.02	1.75E-27	VLDLR	28458	KCNV2	34582	INTERGENIC	0.97	1
rs10125071	9	2669579	C	0.40	-0.21	0.02	5.88E-27	VLDLR	25094	KCNV2	37946	INTERGENIC	1.00	1
rs4317630	9	2671025	C	0.39	-0.21	0.02	9.65E-27	VLDLR	26540	KCNV2	36500	INTERGENIC	0.98	1
rs10122587	9	2681951	T	0.28	-0.22	0.02	3.02E-24	KCNV2	25574	VLDLR	37466	INTERGENIC	0.98	1
rs9361273	6	44084246	G	0.01	5.92	0.59	5.37E-24	MGC45491	3361	MIRPL14	105103	DOWNSTREAM	0.03	1
rs7747448	6	43980902	A	0.34	-0.25	0.03	6.88E-23	MGC45491	85414	VEGFA	128703	INTRONIC	0.58	1

FIG. 6A

SNP	Chr	Position	CA	CAF	beta	SE	P	Gene 1	Distance	Gene 2	Distance	Function	OE ratio	Impaired
rs4276495	6	43981237	T	0.32	-0.23	0.02	6.46E-22	MGC45491	85079	VEGFA	123038	INTRONIC	0.69	1
rs10117473	9	2670425	G	0.21	-0.22	0.02	7.67E-22	VLDLR	25940	KCNV2	37100	INTERGENIC	1.01	1
rs10967492	9	2671175	A	0.21	-0.22	0.02	1.02E-21	VLDLR	36690	KCNV2	36350	INTERGENIC	1.01	1
rs10967470	9	2665698	G	0.24	-0.22	0.02	1.17E-21	VLDLR	21213	KCNV2	41827	INTERGENIC	0.97	1
rs10812475	9	2681546	C	0.21	-0.22	0.02	1.84E-21	KCNV2	25979	VLDLR	37061	INTERGENIC	0.96	1
rs10812474	9	2681446	G	0.21	-0.22	0.02	1.86E-21	KCNV2	26079	VLDLR	36961	INTERGENIC	0.98	1
rs10812473	9	2681329	A	0.21	-0.22	0.02	1.86E-21	KCNV2	26196	VLDLR	36844	INTERGENIC	0.98	1
rs10812471	9	2680980	T	0.21	-0.22	0.02	1.89E-21	KCNV2	26645	VLDLR	36495	INTERGENIC	0.98	1
rs10125245	9	2679244	T	0.21	-0.22	0.02	2.09E-21	KCNV2	26281	VLDLR	34759	INTERGENIC	1.00	1
rs10967512	9	2673939	C	0.21	-0.22	0.02	2.18E-21	VLDLR	29454	KCNV2	33586	INTERGENIC	1.02	0
rs10757628	9	2674656	T	0.21	-0.22	0.02	2.22E-21	VLDLR	30171	KCNV2	32869	INTERGENIC	1.01	0
rs10812472	9	2681095	G	0.20	-0.23	0.02	4.88E-21	KCNV2	26430	VLDLR	36610	INTERGENIC	0.94	1
rs7667894	9	2665867	C	0.25	-0.21	0.02	8.62E-21	VLDLR	21382	KCNV2	41858	INTERGENIC	0.98	1
rs9472175	6	44042760	T	0.15	-0.56	0.06	9.73E-21	MGC45491	33556	MRPL14	146589	INTERGENIC	0.20	1
rs1776717	6	44059314	A	0.21	-0.23	0.02	8.10E-20	MGC45491	17002	MRPL14	130035	INTERGENIC	0.85	1
rs910609	6	44059634	A	0.21	-0.23	0.02	9.14E-20	MGC45491	16682	MRPL14	129715	INTERGENIC	0.86	1
rs833623	6	44008785	C	0.41	0.18	0.02	1.07E-19	MGC45491	89561	VEGFA	144556	INTRONIC	0.92	1
rs833622	6	44008382	T	0.40	0.17	0.02	1.21E-19	MGC45491	67934	VEGFA	146183	INTRONIC	0.98	0
rs1776721	6	43989961	T	0.30	-0.18	0.02	1.52E-19	MGC45491	77355	VEGFA	136762	INTRONIC	0.99	0
rs9581267	6	44013484	G	0.41	0.17	0.02	3.15E-19	MGC45491	62832	VEGFA	151285	3PRIME_UTR	0.97	1
rs1898979	6	44012679	G	0.41	0.17	0.02	3.72E-19	MGC45491	63437	VEGFA	150660	3PRIME_UTR	0.97	0
rs10122524	9	2681667	T	0.30	-0.19	0.02	3.73E-19	KCNV2	25858	VLDLR	37182	INTERGENIC	0.99	1
rs9472155	6	44005705	T	0.22	-0.20	0.02	4.45E-19	MGC45491	70611	VEGFA	143506	INTRONIC	0.96	1
rs7767550	6	44007230	A	0.22	-0.20	0.02	6.36E-19	MGC45491	69086	VEGFA	145031	INTRONIC	0.98	0
rs3888006	6	44000916	A	0.22	-0.20	0.02	7.60E-19	MGC45491	75400	VEGFA	138717	INTRONIC	0.95	1
rs1750570	6	44000213	T	0.22	-0.20	0.02	8.79E-19	MGC45491	76103	VEGFA	138014	INTRONIC	0.95	1
rs1326141	6	44011265	A	0.22	-0.20	0.02	2.43E-18	MGC45491	65061	VEGFA	149056	INTRONIC	0.98	0
rs106608	6	44059804	C	0.22	-0.21	0.02	3.39E-18	MGC45491	16512	MRPL14	129545	INTERGENIC	0.87	1
rs7356919	6	43999343	A	0.22	-0.20	0.02	5.37E-18	MGC45491	76973	VEGFA	137144	INTRONIC	0.96	1
rs910610	6	44059418	A	0.23	-0.21	0.03	2.50E-17	MGC45491	16898	MRPL14	139931	INTERGENIC	0.79	1
rs1418698	6	44027285	A	0.01	-2.60	0.31	7.27E-17	MGC45491	49031	MRPL14	162064	INTERGENIC	0.14	1
rs1418697	6	44027365	G	0.01	-2.60	0.31	7.37E-17	MGC45491	48951	MRPL14	161984	INTERGENIC	0.14	1
rs9296424	6	44043864	C	0.18	-0.49	0.06	9.98E-17	MGC45491	32452	MRPL14	145485	INTERGENIC	0.18	1

FIG. 6B

SNP	Chr	Position	CA	CAF	beta	SE	P	Gene 1	Distance	Gene 2	Distance	Function	O/E ratio	Imputed
rs1631938	6	44060024	A	0.23	-0.20	0.02	1.74E-16	MGC45491	16292	MRPL14	129325	INTERGENIC	0.83	1
rs7761865	6	43976194	G	0.36	-0.81	0.06	2.21E-16	MGC45481	100122	VEGFA	113995	INTRONIC	0.10	1
rs6993770	8	106650704	T	0.32	-0.17	0.02	2.50E-16	ZFPM2	0	LRP12	980360	INTRONIC	0.97	1
rs9367181	6	44064593	G	0.20	-0.19	0.02	3.61E-16	MGC45491	11723	MRPL14	124756	INTERGENIC	0.98	0
rs1740074	6	44055768	G	0.06	-0.46	0.06	8.17E-16	MGC45491	20548	MRPL14	133581	INTERGENIC	0.44	1
rs11968152	6	43944908	A	0.04	1.16	0.14	1.18E-15	VEGFA	82709	MGC45491	131408	INTERGENIC	0.11	1
rs3932536	6	43944278	A	0.04	1.15	0.14	1.43E-15	VEGFA	82079	MGC45491	132036	INTERGENIC	0.11	1
rs6936668	6	43944048	C	0.04	1.15	0.14	1.45E-15	VEGFA	81849	MGC45491	132266	INTERGENIC	0.11	1
rs7832219	8	106848153	C	0.30	-0.16	0.02	1.72E-15	ZFPM2	0	LRP12	977808	INTRONIC	0.98	1
rs4734879	8	106852300	G	0.30	-0.16	0.02	1.78E-15	ZFPM2	0	LRP12	981956	INTRONIC	0.98	1
rs2343592	8	106841446	G	0.30	-0.16	0.02	1.98E-15	ZFPM2	0	LRP12	971102	INTRONIC	0.97	1
rs4734875	8	106823913	C	0.26	-0.16	0.02	9.46E-15	ZFPM2	0	LRP12	953568	INTRONIC	1.00	0
rs16873346	8	106618657	C	0.26	-0.16	0.02	1.07E-14	ZFPM2	0	LRP12	948313	INTRONIC	0.99	1
rs644294	6	44008665	C	0.51	-0.15	0.02	1.19E-14	MGC45491	67631	VEGFA	146496	INTRONIC	0.97	1
rs4236085	6	43971742	C	0.38	-0.43	0.06	1.27E-14	MGC45491	104574	VEGFA	109543	INTRONIC	0.12	1
rs16873402	8	106658423	T	0.33	-0.15	0.02	1.97E-14	ZFPM2	0	LRP12	988079	INTRONIC	0.99	1
rs910604	6	44061649	A	0.20	-0.18	0.02	2.15E-14	MGC45491	14667	MRPL14	127700	INTERGENIC	0.98	0
rs16873418	8	106661321	G	0.33	-0.15	0.02	2.28E-14	ZFPM2	0	LRP12	990977	INTRONIC	0.99	1
rs6931378	6	43982797	A	0.50	0.37	0.05	7.27E-14	MGC45491	93519	VEGFA	120596	INTRONIC	0.14	1
rs4416670	6	44058431	T	0.55	0.13	0.02	1.47E-12	MGC45491	17685	MRPL14	130918	INTERGENIC	0.99	0
rs1740077	6	44057885	C	0.56	0.13	0.02	5.21E-12	MGC45491	18431	MRPL14	131464	INTERGENIC	0.96	1
rs1776704	6	44057919	G	0.56	0.13	0.02	5.38E-12	MGC45491	18397	MRPL14	131430	INTERGENIC	0.96	1
rs16873365	8	106627411	T	0.21	-0.16	0.02	5.65E-12	ZFPM2	0	LRP12	957067	INTRONIC	0.92	1
rs1776706	6	44057965	C	0.56	0.13	0.02	5.79E-12	MGC45491	18351	MRPL14	131384	INTERGENIC	0.97	1
rs4320369	6	44058040	C	0.56	0.13	0.02	5.98E-12	MGC45491	18276	MRPL14	131309	INTERGENIC	0.97	1
rs1740079	6	44059217	T	0.56	0.13	0.02	6.02E-12	MGC45491	17099	MRPL14	130132	INTERGENIC	0.96	1
rs910612	6	44058664	T	0.44	-0.13	0.02	6.07E-12	MGC45491	17632	MRPL14	130665	INTERGENIC	0.97	1
rs910613	6	44058614	T	0.56	0.13	0.02	6.10E-12	MGC45491	17702	MRPL14	130735	INTERGENIC	0.97	1
rs910614	6	44058596	T	0.44	-0.13	0.02	6.12E-12	MGC45491	17720	MRPL14	130753	INTERGENIC	0.97	1
rs7013321	8	106662734	A	0.48	-0.14	0.02	6.75E-12	ZFPM2	0	LRP12	992390	INTRONIC	0.83	1
rs8993696	8	106650460	A	0.48	-0.13	0.02	8.54E-12	ZFPM2	0	LRP12	980116	INTRONIC	0.99	1
rs4741755	9	2657929	C	0.30	-0.23	0.03	2.26E-11	VLDLR	13444	KCNV2	48596	INTERGENIC	0.37	1
rs16873287	8	106597151	G	0.30	-0.13	0.02	5.13E-11	ZFPM2	0	LRP12	926807	INTRONIC	1.02	0

FIG. 6C

SNP	Chr	Position	CA	CAF	beta	SE	P	Gene 1	Distance	Gene 2	Distance	Function	O/E ratio	Imputed
rs16373291	8	106591206	T	0.30	-0.13	0.02	5.30E-11	ZFPM2	0	LRP12	926862	INTRONIC	1.02	0
rs12676726	8	106597884	C	0.30	-0.13	0.02	5.44E-11	ZFPM2	0	LRP12	927540	INTRONIC	1.01	1
rs9472147	6	43944737	A	0.17	-0.49	0.07	6.78E-11	VEGFA	62538	MGC45491	131579	INTERGENIC	0.12	1
rs10105733	8	106595037	G	0.29	-0.14	0.02	6.09E-11	ZFPM2	0	LRP12	924693	INTRONIC	1.01	1
rs4794119	8	106599899	G	0.30	-0.13	0.02	7.33E-11	ZFPM2	0	LRP12	929355	INTRONIC	1.01	0
rs1157141	8	106600486	G	0.30	-0.13	0.02	7.33E-11	ZFPM2	0	LRP12	930142	INTRONIC	1.01	1
rs1157142	8	106600850	A	0.30	-0.13	0.02	7.34E-11	ZFPM2	0	LRP12	930506	INTRONIC	1.01	1
rs6996138	8	106601653	G	0.30	-0.13	0.02	7.35E-11	ZFPM2	0	LRP12	931309	INTRONIC	1.01	1
rs4734873	8	106602506	A	0.30	-0.13	0.02	7.36E-11	ZFPM2	0	LRP12	932162	INTRONIC	1.01	0
rs7001868	8	106602795	G	0.30	-0.13	0.02	7.38E-11	ZFPM2	0	LRP12	932451	INTRONIC	1.01	1
rs10094510	8	106592361	A	0.29	-0.13	0.02	8.33E-11	ZFPM2	0	LRP12	922017	INTRONIC	1.02	0
rs7007568	8	106591021	G	0.29	-0.13	0.02	9.27E-11	ZFPM2	0	LRP12	920677	INTRONIC	1.02	1
rs16873231	8	106587411	G	0.29	-0.13	0.02	1.36E-10	ZFPM2	0	LRP12	917067	INTRONIC	1.01	1
rs6997293	8	106587104	C	0.29	-0.13	0.02	1.47E-10	ZFPM2	0	LRP12	916760	INTRONIC	1.01	1
rs1868650	8	106587086	C	0.29	-0.13	0.02	1.52E-10	ZFPM2	0	LRP12	918744	INTRONIC	1.01	1
rs1868649	8	106587041	A	0.29	-0.13	0.02	1.57E-10	ZFPM2	0	LRP12	918697	INTRONIC	1.01	1
rs2291192	8	106586246	A	0.29	-0.13	0.02	1.77E-10	ZFPM2	0	LRP12	915904	INTRONIC	1.01	1
rs12678719	8	106565230	G	0.29	-0.13	0.02	1.95E-10	ZFPM2	0	LRP12	914686	INTRONIC	1.01	1
rs10093110	8	106634590	A	0.43	-0.12	0.02	2.18E-10	ZFPM2	0	LRP12	964246	INTRONIC	0.99	0
rs6988664	8	106582477	G	0.29	-0.13	0.02	2.33E-10	ZFPM2	0	LRP12	912133	INTRONIC	1.01	1
rs4734869	8	106582004	A	0.29	-0.13	0.02	2.60E-10	ZFPM2	0	LRP12	911660	INTRONIC	1.01	0
rs910611	6	44058829	C	0.08	-0.26	0.04	2.61E-10	MGC45491	17487	MRPL14	130520	INTERGENIC	0.77	1
rs746785	9	2684347	C	0.13	0.24	0.04	1.01E-09	KGNV2	23178	VLDLR	39862	INTERGENIC	0.52	1
rs7767854	6	44065304	T	0.11	-0.22	0.04	1.02E-09	MGC45491	11012	MRPL14	124045	INTERGENIC	0.74	1
rs6996272	8	106662838	T	0.46	0.14	0.02	1.98E-09	ZFPM2	0	LRP12	992494	INTRONIC	0.68	1
rs12675041	8	106598221	A	0.34	-0.12	0.02	2.10E-09	ZFPM2	0	LRP12	927877	INTRONIC	0.96	1
rs1740080	5	44060390	A	0.12	-0.18	0.03	2.76E-09	MGC45491	15926	MRPL14	128959	INTERGENIC	0.93	1
rs910606	6	44061307	A	0.12	-0.18	0.03	2.90E-09	MGC45491	15008	MRPL14	128042	INTERGENIC	0.94	0
rs1631662	6	44061336	T	0.12	-0.18	0.03	2.93E-09	MGC45491	14980	MRPL14	128013	INTERGENIC	0.94	1
rs2051074	6	44066431	T	0.04	-0.41	0.07	5.80E-09	MGC45491	19885	MRPL14	132918	INTERGENIC	0.46	1
rs9381262	6	43983427	A	0.45	-0.29	0.05	6.78E-09	MGC45491	92669	VEGFA	121228	INTRONIC	0.14	1
rs1450183	8	106601296	C	0.37	-0.11	0.02	1.11E-08	ZFPM2	0	LRP12	939954	INTRONIC	1.00	1

FIG. 6D

SNP	Chr	Position	CA	CAF	beta	SE	P	Gene 1	Distance	Gene 2	Distance	Function	O/E ratio	Imputed
rs7836542	8	106603619	T	0.37	-0.11	0.02	1.13E-08	ZFPM2	0	LRP12	933275	INTRONIC	1.01	0
rs16897113	8	44076194	T	0.03	0.62	0.11	1.34E-08	MGC45491	122	MRPL14	113155	UPSTREAM	0.29	1
rs2343595	8	106660383	G	0.45	-0.11	0.02	2.26E-08	ZFPM2	0	LRP12	990039	INTRONIC	1.01	1
rs16873415	8	106660878	G	0.45	-0.11	0.02	2.39E-08	ZFPM2	0	LRP12	990634	INTRONIC	1.01	0
rs1901061	8	106619426	A	0.39	0.11	0.02	3.08E-08	ZFPM2	0	LRP12	949082	INTRONIC	0.94	1
rs1349319	8	106625810	A	0.39	0.11	0.02	3.59E-08	ZFPM2	0	LRP12	955466	INTRONIC	0.94	1
rs9369430	6	43942229	G	0.16	0.24	0.04	3.68E-08	VEGFA	80030	MGC45491	134087	INTERGENIC	0.33	1
rs748786	9	2684436	T	0.12	0.23	0.04	3.81E-08	KCNV2	23089	VLDLR	39951	INTERGENIC	0.52	1
rs4734122	8	106629546	A	0.41	0.11	0.02	4.15E-08	ZFPM2	0	LRP12	959202	INTRONIC	0.99	1
rs1375955	8	106624215	T	0.39	0.11	0.02	4.30E-08	ZFPM2	0	LRP12	953871	INTRONIC	0.94	1
rs12679049	8	106598022	G	0.22	-0.12	0.02	4.75E-08	ZFPM2	0	LRP12	927678	INTRONIC	0.99	0

CA: coded allele; CAF: coded allele frequency; Chr: chromosome; KCNV2: potassium voltage-gated channel subfamily V, member 2; LRP12: low-density lipoprotein receptor-related protein gene; MGC45491: uncharacterized protein, also known as C6orf223; MRPL14: mitochondrial ribosomal protein L14; O/E ratio: observed over expected ratio (measuring imputation accuracy); p: p-value; SE: standard error; SNP: single nucleotide polymorphism; VEGF: vascular endothelial growth factor; VLDLR: very low density lipoprotein receptor; ZFPM2: zinc finger protein, multitype 2.

FIG. 6E

SNP	Chr	Position	Function	CAF	Coded strand	beta <sup>1</sup> (FHS)	SE (FHS)	p (FHS) <sup>1</sup>	p (PIVUS) <sup>2</sup>	p (SFS) <sup>3</sup>	Dir	Meta-p (FHS-PIVUS) <sup>4</sup>	Meta-p (af) <sup>5</sup>	Gene1	Distance (Kb)	Gene2	Distance (Kb)
rs6921438	6	44033585	intergenic	0.51	G	+ 0.72	0.01	6.11x10 <sup>-26</sup>	NA	2.93x10 <sup>-20</sup>	-?	6.11x10 <sup>-26</sup>	4.44x10 <sup>-23</sup>	MGC45491	42.7	MRPL14	155.8
rs4613773	6	44033504	intergenic	0.47	G	+ -0.70	0.01	2.08x10 <sup>-03</sup>	6.23x10 <sup>-18</sup>	NA	++?	4.45x10 <sup>-013</sup>	1.10x10 <sup>-09</sup>	MGC45491	42.8	MRPL14	155.8
rs9472156	6	44027673	intergenic	0.50	C	+ 0.76	0.02	4.30x10 <sup>-02</sup>	3.27x10 <sup>-03</sup>	4.11x10 <sup>-25</sup>	—	1.61x10 <sup>-087</sup>	6.16x10 <sup>-53</sup>	MGC45491	48.6	MRPL14	161.7
rs9369434	6	44026385	intergenic	0.53	C	+ 0.84	0.02	2.15x10 <sup>-02</sup>	1.43x10 <sup>-01</sup>	5.31x10 <sup>-28</sup>	—	1.43x10 <sup>-090</sup>	1.21x10 <sup>-138</sup>	MGC45491	49.9	MRPL14	163.0
rs1776717	6	44059314	intergenic	0.21	A	+ -0.23	0.02	8.10x10 <sup>-29</sup>	3.74x10 <sup>-01</sup>	9.75x10 <sup>-04</sup>	—	3.28x10 <sup>-22</sup>	1.07x10 <sup>-25</sup>	MGC45491	17.0	MRPL14	130.0
rs1776721	6	43988961	Intronic	0.31	T	+ -0.18	0.02	1.52x10 <sup>-19</sup>	3.43x10 <sup>-04</sup>	0.02	—	5.38x10 <sup>-24</sup>	4.23x10 <sup>-25</sup>	MGC45491	77.3	VEGF	136.8
rs1886979	6	44012879	3'UTR	0.41	G	+ 0.17	0.02	3.71x10 <sup>-19</sup>	3.23x10 <sup>-05</sup>	0.01	—	6.55x10 <sup>-34</sup>	1.70x10 <sup>-24</sup>	MGC45491	63.4	VEGF	150.7
rs9472185	6	44005705	Intronic	0.22	T	+ -0.20	0.02	4.45x10 <sup>-19</sup>	3.93x10 <sup>-08</sup>	0.01	—	2.50x10 <sup>-04</sup>	1.51x10 <sup>-28</sup>	MGC45491	70.6	VEGF	143.6
rs844294	6	44008685	Intronic	0.52	C	+ -0.15	0.02	1.16x10 <sup>-14</sup>	2.25x10 <sup>-02</sup>	0.09	+++	1.41x10 <sup>-16</sup>	2.46x10 <sup>-18</sup>	MGC45491	67.6	VEGF	146.5
rs4416670	6	44058431	intergenic	0.55	T	+ 0.13	0.02	1.47x10 <sup>-12</sup>	0.10	2.87x10 <sup>-1</sup>	+++	1.46x10 <sup>-12</sup>	2.09x10 <sup>-15</sup>	MGC45491	17.9	MRPL14	130.9
rs910611	6	44058929	intergenic	0.08	C	+ -0.26	0.04	2.61x10 <sup>-18</sup>	6.36x10 <sup>-08</sup>	0.11	+++	9.92x10 <sup>-15</sup>	1.94x10 <sup>-14</sup>	MGC45491	17.5	MRPL14	130.5
rs6993770	8	106650704	Intronic	0.32	T	+ -0.17	0.02	2.50x10 <sup>-16</sup>	3.99x10 <sup>-08</sup>	0.02	+++	2.60x10 <sup>-22</sup>	4.71x10 <sup>-23</sup>	ZFPM2	0	LRP12	980.4
rs15873402	8	106658423	Intronic	0.33	T	+ -0.15	0.02	1.97x10 <sup>-11</sup>	9.49x10 <sup>-04</sup>	0.16	—	1.10x10 <sup>-20</sup>	5.32x10 <sup>-20</sup>	ZFPM2	0	LRP12	988.1
rs16873365	8	106627411	Intronic	0.22	T	+ -0.16	0.02	5.85x10 <sup>-11</sup>	2.08x10 <sup>-01</sup>	0.37	—	4.10x10 <sup>-16</sup>	2.27x10 <sup>-15</sup>	ZFPM2	0	LRP12	957.1
rs7013321	8	106652734	Intronic	0.49	A	+ -0.14	0.02	6.75x10 <sup>-13</sup>	NA	0.01	-?	6.70x10 <sup>-13</sup>	4.49x10 <sup>-13</sup>	ZFPM2	0	LRP12	992.4
rs6993696	8	106650460	Intronic	0.46	A	+ -0.13	0.02	8.54x10 <sup>-12</sup>	1.49x10 <sup>-04</sup>	0.05	—	6.18x10 <sup>-18</sup>	2.12x10 <sup>-16</sup>	ZFPM2	0	LRP12	990.1
rs15873291	8	106659706	Intronic	0.31	T	+ -0.13	0.02	5.30x10 <sup>-11</sup>	7.65x10 <sup>-1</sup>	0.07	—	1.12x10 <sup>-15</sup>	4.75x10 <sup>-16</sup>	ZFPM2	0	LRP12	926.9
rs1349319	8	106625810	Intronic	0.39	A	+ 0.11	0.02	3.59x10 <sup>-08</sup>	1.32x10 <sup>-2</sup>	0.05	+++	1.59x10 <sup>-18</sup>	3.53x10 <sup>-11</sup>	ZFPM2	0	LRP12	965.5
rs10738760	9	2681186	intergenic	0.49	A	+ 0.28	0.02	1.96x10 <sup>-24</sup>	1.12x10 <sup>-08</sup>	0.03	+++	4.46x10 <sup>-01</sup>	9.93x10 <sup>-09</sup>	KCNV2	26.3	VLDLR	36.7
rs6475920	9	2683933	intergenic	0.36	A	+ -0.24	0.02	3.76x10 <sup>-21</sup>	2.40x10 <sup>-08</sup>	0.02	—	6.11x10 <sup>-29</sup>	7.93x10 <sup>-06</sup>	VLDLR	19.4	KCNV2	43.6
rs4741756	9	2688187	intergenic	0.28	C	+ -0.26	0.02	2.95x10 <sup>-01</sup>	8.64x10 <sup>-2</sup>	0.09	+++	4.45x10 <sup>-24</sup>	3.41x10 <sup>-02</sup>	VLDLR	13.7	KCNV2	49.3
rs2375980	9	2682622	intergenic	0.42	G	+ -0.25	0.02	1.30x10 <sup>-27</sup>	2.25x10 <sup>-9</sup>	0.02	+++	2.65x10 <sup>-24</sup>	1.01x10 <sup>-33</sup>	KCNV2	24.9	VLDLR	38.1
rs10122587	9	2681951	intergenic	0.28	T	+ -0.22	0.02	3.02x10 <sup>-24</sup>	NA	0.02	-?	3.02x10 <sup>-24</sup>	4.67x10 <sup>-28</sup>	KCNV2	25.6	VLDLR	37.5
rs10967482	9	2671175	intergenic	0.21	A	+ -0.22	0.02	1.02x10 <sup>-21</sup>	NA	0.10	-?	1.02x10 <sup>-21</sup>	1.25x10 <sup>-29</sup>	VLDLR	26.7	KCNV2	36.3
rs10967470	9	2666698	intergenic	0.24	G	+ -0.22	0.02	1.17x10 <sup>-21</sup>	NA	0.04	+?+	1.17x10 <sup>-21</sup>	2.79x10 <sup>-21</sup>	VLDLR	21.2	KCNV2	41.8

CAF: Coded Allele Frequency, Chr: chromosome, Dir: Direction of association in FHS, PIVUS, SFS; Gene1: closest referenced gene; Gene2: second closest referenced gene; Meta-p: meta-analysis p-value; SNP: Single Nucleotide Polymorphism; CSE: Standard Error; genome build 36.3; <sup>1</sup>effect estimate for the minor allele; <sup>2</sup>inverse variance meta-analysis; <sup>3</sup>effective sample size weighted meta-analysis; <sup>4</sup>model A: adjusted for age and gender, as well as for the ninth principal component in FHS

FIG. 7

**IDENTIFICATION OF GENETIC VARIANTS**

## RELATED APPLICATIONS

The present application is a divisional of U.S. application Ser. No. 13/594,721, filed Aug. 24, 2012, which claims the benefit of U.S. Provisional Application No. 61/527,531 filed on Aug. 25, 2011. The entireties of which are incorporated herein by reference.

## TECHNICAL FIELD

This disclosure relates to the identification of allelic variation within single nucleotide polymorphisms that can be used to determine susceptibility to VEGF-based therapy.

## BACKGROUND

Vascular endothelial growth factor (VEGF, also referred to as VEGFA in contrast to other members of the VEGF family) is pivotal in many physiological and pathological processes. It is primarily known for its key role in the stimulation of angiogenesis, with a potent mitogenic effect on vascular endothelial cells from arteries, veins and lymphatics. VEGF also promotes vasodilatation by inducing the production of nitric oxide and prostacyclin by endothelial cells. In addition, VEGF is involved in hematopoietic development and chemotaxis of monocytes, regulation of osteoclast differentiation, stimulation of surfactant production, and has neurotrophic and neuroprotective effects on neuronal and glial cells. Elevated circulating VEGF levels have been observed in vascular disease (ischemic heart disease, heart failure, stroke), and in various other disorders, including diabetes, cognitive decline and dementia, reproductive, immune-inflammatory disorders, and neoplastic diseases. Administration of VEGF promotes angiogenesis in patients with critical leg ischemia, as well as in animal models of coronary and limb ischemia. VEGF inhibitors such as bevacizumab and sorafenib have been successfully used to inhibit angiogenesis in several tumors, in macular degeneration and in rheumatoid arthritis.

However, despite the considerable toxicity associated with VEGF inhibitor drugs, to date there have been no pharmacogenomic studies to identify potential sub-groups of responders partly because the genetic determinants of VEGF concentrations remain poorly understood.

Indeed, although the heritability of circulating VEGF levels is very high, ranging between 60 and 80%, few studies have assessed the relationship between circulating VEGF levels and genetic variants.

Candidate gene studies exploring associations between VEGF polymorphisms and circulating VEGF levels have yielded controversial results. Eight studies have found significant associations with candidate polymorphisms (rs699947, rs1570360, rs833061, rs2010963, rs3025039 and -2549 18 bp I/D) in the promoter, 5' and 3' untranslated region of the VEGF gene. However, several other studies did not identify any association with these and other VEGF SNPs.

While several studies have examined the association of candidate genetic variants with VEGF gene expression in pathological tissues, little is known about the genetic variants influencing VEGF expression in normal cells.

Therefore, there is a need for greater understanding of polymorphisms linked to VEGF levels, in order to identify patients who are more likely to respond favorably to anti-VEGF and pro-angiogenic VEGF based treatments. Such

therapies can have major side-effects, and optimizing the risk to benefit ratio of their administration could lead to substantial improvements in patient care.

## SUMMARY

According to a first aspect, the present disclosure provides a method for identifying whether a subject is likely to be more or less responsive to VEGF-based therapy, comprising screening a nucleic acid sample obtained from the subject to provide output information which identifies the presence or absence of an allelic variant, wherein the allelic variant is selected from the group consisting of: (i) rs6921438; (ii) rs4416670; (iii) rs6993770; and (iv) rs10738760, and wherein the presence or absence of the allelic variant indicates that the subject is likely to be more or less likely to be responsive to VEGF based therapy.

According to a second aspect, the present disclosure provides a method for identifying whether a subject is likely to be more or less responsive to VEGF-based therapy, comprising screening a nucleic acid sample obtained from the subject to provide output information which identifies the presence or absence of at least one allelic variant associated with VEGF mRNA, wherein the at least one allelic variant is selected from the group consisting of: (i) rs16873365; (ii) rs16873402; (iii) rs6993770; (iv) rs16873291; (v) rs2375980; and (vi) rs910611, wherein the presence or absence of the allelic variant indicates that the subject is more or less likely to be responsive to VEGF-based therapy.

According to a third aspect, the present disclosure provides a method for identifying whether a subject is likely to be more or less responsive to VEGF-based therapy, comprising screening a sample obtained from a subject to determine the level of expression of one or more of the VLDLR, LRP12, ZFPM2 and KCNV2 genes, and comparing against a control value, wherein an increase in expression compared to the control indicates that the patient is more or less likely to be responsive to VEGF or anti-VEGF therapy.

According to a fourth aspect, the present disclosure provides a method for identifying molecules that affect the level of circulating VEGF in a subject, comprising screening a target molecule to provide output information to establish whether the molecule affects the activity of the product of any of the VLDLR, LRP12, ZFPM2 and KCNV2 genes, wherein a molecule that inhibits the activity will alter the level of circulating VEGF in vivo.

According to a fifth aspect, the present disclosure provides a method for administering a VEGF-based therapy to a subject, the method comprising the step of screening a nucleic acid sample obtained from the subject to provide output information which identifies the presence or absence of an allelic variant, wherein the allelic variant is selected from the group consisting of: (i) rs6921438, (ii) rs4416670, (iii) rs6993770, and (iv) rs10738760, wherein if the nucleic acid sample is screened for the allelic variant rs6921438 and a guanine residue is detected at base 323 of SEQ ID No. 1 at one or both alleles, a VEGF-based therapy is administered, wherein if the nucleic acid sample is screened for the allelic variant rs4416670 and a thymine residue is detected at base 221 of SEQ ID No. 2 at one or both alleles, a VEGF-based therapy is administered, wherein if the nucleic acid sample is screened for the allelic variant rs6993770 and a thymine residue is detected at base 235 of SEQ ID No. 3 at one or both alleles, a VEGF-based therapy is not administered, wherein if the nucleic acid sample is screened for the

allelic variant rs10738760 and a guanine residue is detected at base 201 of SEQ ID No. 4 at one or both alleles, a VEGF-based therapy is administered.

According to a sixth aspect, the present disclosure provides an array comprising one or more reagents deposited on a substrate, wherein the reagents have affinity for and/or hybridize to, one or more polynucleotides comprising single nucleotide polymorphisms identified herein as rs6921438, rs4416670, rs6993770, rs10738760, rs16873365, rs16873402, rs16873291, rs2375980, rs910611 and/or wherein the reagents have affinity for and/or hybridize to one or more of the genes selected from VLDLR, LRP12, ZFPM2 and KCNV2.

#### BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is a QQ-plot showing the observed versus the expected p-values after meta-analysis for serum VEGF levels (the solid line shows the distribution under the null-hypothesis).

FIG. 2 is a Manhattan plot showing individual p-values against their genomic position for GWAS of serum VEGF levels. Within each chromosome (x-axis), results are plotted left to right from p-terminal end. Dashed line indicates preset threshold for genome-wide significance,  $p=5.0 \times 10^{-8}$ ; solid line threshold for suggestive associations,  $p=4.0 \times 10^{-7}$ .

FIGS. 3A-3C show regional plots for associations in region centered on rs6921438 (FIG. 3A), rs6993770 (FIG. 3B) and rs10738760 (FIG. 3C).

FIG. 4 shows the genomic organization of the VEGF gene and localization of the SNPs identified in the genetic association and transcriptomic studies.

FIG. 5 shows a Putative Gene Network based on Ingenuity Path Analysis. Edges are displayed with labels describing the nature of the relationship between the nodes. Lines between genes represent known interactions and the nodes are displayed using various shapes which represent the functional class of the gene product (legend).

FIGS. 6A-6E is a single table showing certain properties of SNPs identified by genome-wide genotyping.

FIG. 7 is a table showing selected properties of SNPs identified by genome-wide genotyping.

#### DETAILED DESCRIPTION

The present disclosure is based on the identification of novel genetic variants associated with circulating VEGF levels, on chromosomes 6, 8 and 9. In particular, four single nucleotide polymorphisms (SNPs) have been identified that play a key role in determining serum VEGF levels. These SNPs are: rs6921438; rs4416670; rs6993770; and rs10738760. Allelic variation in these four SNPs has been found to account for approximately 48% of the heritability of serum VEGF levels. Allelic variation at a single SNP, rs6921438, has been found to account for approximately 42% of phenotypic variance in serum VEGF levels. Determining genetic variation at these SNPs enables clinicians to identify patients who are more likely to respond favorably to anti-VEGF and/or pro-angiogenic VEGF-based treatments.

rs6921438 is located on chromosome 6p21.1 and is identified herein as base 323 of SEQ ID No. 1. The wild-type nucleotide at this position is adenine (A) (coded allele frequency 0.49); however the presence of guanine (G) (coded allele frequency 0.51) instead of adenine is indicative of increased association with VEGF. As such, those subjects

having G at this position are more likely to respond favorably to VEGF-based treatment, in particular, anti-VEGF therapies.

rs4416670 is located on chromosome 6p21.1 and is identified herein as base 221 of SEQ ID NO. 2. The wild-type nucleotide at this position is cytosine (C) (coded allele frequency 0.45); however the presence of thymine (T) (coded allele frequency 0.55) instead of cytosine is indicative of increased association with VEGF. As such, those subjects having T at this position are more likely to respond favorably to VEGF-based treatment.

rs6993770 is located on chromosome 8q23.1 and is identified herein as base 235 of SEQ ID No. 3. The wild-type nucleotide at this position is adenine (A) (coded allele frequency 0.68). The presence of thymine (T) (coded allele frequency 0.32) instead of adenine is indicative of decreased association with VEGF. As such, those subjects having T at this position are less likely to respond favorably to VEGF-based treatment.

rs10738760 is located on chromosome 9p24.2 and is identified herein as base 201 of SEQ ID NO. 4. The wild-type nucleotide at this position is adenine (A) (coded allele frequency 0.49); however the presence of guanine (G) (coded allele frequency 0.51) instead of adenine is indicative of increased association with VEGF. As such, those subjects having G at this position are more likely to respond favorably to VEGF-based treatment.

Accordingly, a first aspect of the present disclosure provides a method for identifying whether a subject is more or less likely to be responsive to VEGF or anti-VEGF therapy, comprising screening a nucleic acid sample obtained from the subjects for the presence or absence of an allelic variant, wherein the allelic variant is selected from the group consisting of: (i) rs6921438; (ii) rs4416670; (iii) rs6993770; and (iv) rs10738760, and wherein the presence or absence of the allelic variant indicates that the subject is more or less likely to be responsive VEGF-based therapy.

The present disclosure is useful when considering a VEGF-based therapy for a patient suffering from a disease or condition that is associated with high or low circulating VEGF levels. Prior to administering a VEGF-based therapy, a patient can be screened to determine how responsive they are likely to be to the VEGF-based therapy. In this context, the method of the disclosure could be used to screen a patient requiring pro-VEGF therapy (for example, to promote angiogenesis to treat ischemia) or, alternatively, to screen a patient requiring anti-VEGF therapy (for example, for the treatment of a tumor). The methods of the disclosure are equally applicable to both cases. However, in a preferred embodiment the patient has a condition that can be treated by administering anti-VEGF drugs, and therefore the method of the disclosure is used to screen for the likelihood that the patient will be responsive to anti-VEGF therapy.

As used herein, the term "VEGF-based therapy" refers to treatments and/or drugs which inhibit or promote VEGF activity. Therefore, "VEGF-based therapy" includes both anti-VEGF therapies and pro-VEGF therapies. Examples of anti-VEGF drugs (also known as VEGF-inhibitors) include bevacizumab (Avastin™), ranibizumab (Lucentis™), lapatinib (Tykerb™), sunitinib (Sutent™), sorafenib (Nexavar™), axitinib, pazopanib and thiazolidinediones. Pro-VEGF therapies enhance the activity or function of VEGF and are used clinically to promote angiogenesis.

The nucleic acid sample can be isolated from a biological sample, such as a blood sample, taken from a patient. The skilled person will be familiar with conventional techniques for obtaining isolated nucleic acid samples from individual

subjects. As used herein, the term “screening” refers to carrying out an assay to identify allelic variation at specified locations within the subject’s genome. Preferably, the screening step takes place in vitro.

Furthermore, six SNPs have been identified as being associated with VEGF mRNA levels. These SNPs are summarized in Table 5.

rs16873365 is located on chromosome 8 and is identified herein as base 251 of SEQ ID No. 5.

rs16873402 is located on chromosome 8 and is identified herein as base 251 of SEQ ID No. 6.

rs6993770 is located on chromosome 8 and is identified herein as base 235 of SEQ ID No. 3. As described above, this SNP is also associated with VEGF peptide levels.

rs16873291 is located on chromosome 8 and is identified herein as base 251 of SEQ ID No. 7.

rs2375980 is located on chromosome 9 and is identified herein as base 501 of SEQ ID No. 8. The wild-type nucleotide at this position is guanine (G) (coded allele frequency 0.42).

rs910611 is located on chromosome 6 and is identified herein as base 301 of SEQ ID No. 9.

Therefore, according to a second aspect of this disclosure, a method for identifying whether a subject is more or less likely to be responsive to VEGF-based therapy comprises screening a nucleic acid sample obtained from the subjects for the presence or absence of at least one allelic variant associated with VEGF mRNA, wherein the at least one allelic variant is selected from the group consisting of: (i) rs16873365; (ii) rs16873402; (iii) rs6993770; (iv) rs16873291; (v) rs2375980; and (vi) rs910611, wherein the presence or absence of the allelic variant indicates that the subject is more or less likely to be responsive to VEGF-based therapy.

According to a third aspect of the present disclosure, a method for identifying whether a subject is more or less likely to be responsive to VEGF-based therapy, comprises determining the level of expression of one or more of the VLDLR, LRP12, ZFPM2 and KCNV2 genes in a sample obtained from a patient, and comparing against a control value, wherein an increase in expression compared to the control indicates that the subject is more or less likely to be responsive to VEGF-based therapy.

VLDLR (Very low-density lipoprotein receptor) is located at chromosomal position 9p24 and is identified by the Human Gene Nomenclature Committee as HGNC:12698.

LRP12 (Low-density lipoprotein receptor-related protein 12) is located at chromosomal position 8q22.2 and is identified by the Human Gene Nomenclature Committee as HGNC:31708.

ZFPM2 (Zinc finger protein ZFPM2) is located at chromosomal position 8q23 and is identified by the Human Gene Nomenclature Committee as HGNC:16700.

KCNV2 (Potassium voltage-gated channel subfamily V member 2) is located at chromosomal position 9p24.2 and is identified by the Human Gene Nomenclature Committee as HGNC:19698.

As used herein the term “expression level” refers to the amount of a specified protein (or mRNA coding for the protein) in a patient’s sample. The expression level is then compared to that of a control sample.

Methods of measuring the level of expression of a protein from a biological sample are well known in the art and any suitable method may be used. Protein or nucleic acid from the sample may be analyzed to determine the expression level. An example of a suitable method is a quantitative PCR

reaction or mRNA (or cDNA) obtained from the patient’s sample. The use of quantitative PCR to detect gene expression levels is well known in the art. Kits for quantitative PCR-based gene expression analysis are commercially available, for example the Quantitect system manufactured by Qiagen. Simultaneous analysis of expression levels in multiple samples using a hybridization-based nucleic acid array system is well known in the art and is also within the scope of the disclosure.

Preferably, the expression level of specific gene products is quantified in terms of “standardized abundance”, which provides a numerical value that takes into account natural variation in the concentration of a given protein in a biological sample. The standardized abundance value enables comparison with a known control value.

In one embodiment, the methods of the first, second and/or third aspects of the disclosure can be combined, such that a patient sample is screened for the presence or absence of one or more allelic variants and the expression level of one or more of the genes VLDLR, LRP12, ZFPM2 and KCNV2 is also determined. The output information from these methods is combined to provide an overall output corresponding to likelihood of responsiveness to VEGF-based therapy.

According to a fourth aspect of the present disclosure, a method for identifying molecules that affect the level of circulating VEGF in a subject comprises screening a target molecule to establish whether it affects (i.e. inhibits or enhances) the activity of the product of any of the VLDLR, LRP12, ZFPM2 and KCNV2 genes, wherein a molecule that affects the activity will alter (increase or decrease) the level of circulating VEGF in vivo.

As used in the context of the fourth aspect, the term “screening” refers to carrying out an assay to identify whether a target molecule affects the activity of one or more of the genes specified. Preferably, the screening step takes place in vitro.

The terms “circulating VEGF levels” and “serum VEGF levels” are used interchangeably herein.

The terms “subject” and “patient” are used interchangeably throughout this description and refer to an animal, preferably a mammal, and most preferably a human. Preferably, the subject has a disease or condition that may be treated using VEGF-based therapy.

According to a fifth aspect, the present disclosure provides a method for administering a VEGF-based therapy to a subject, the method comprising the step of screening a nucleic acid sample obtained from the patient to provide output information which identifies the presence or absence of an allelic variant, wherein the allelic variant is selected from the group consisting of: (i) rs6921438, (ii) rs4416670, (iii) rs6993770, and (iv) rs10738760, wherein if the nucleic acid sample is screened for the allelic variant rs6921438 and a guanine residue is detected at base 323 of SEQ ID No.1 at one or both alleles, a VEGF-based therapy is administered, wherein if the nucleic acid sample is screened for the allelic variant rs4416670 and a thymine residue is detected at base 221 of SEQ ID No. 2 at one or both alleles, a VEGF-based therapy is administered, wherein if the nucleic acid sample is screened for the allelic variant rs6993770 and a thymine residue is detected at base 235 of SEQ ID No. 3 at one or both alleles, a VEGF-based therapy is not administered, wherein if the nucleic acid sample is screened for the allelic variant rs10738760 and a guanine residue is detected at base 201 of SEQ ID No. 4 at one or both alleles, a VEGF-based therapy is administered.

Preferably, the VEGF-based therapy is an anti-VEGF drug, which may be selected from bevacizumab (Avastin™), ranibizumab (Lucentis™), lapatinib (Tykerb™), sunitinib (Sutent™), sorafenib (Nexavar™), axitinib, pazopanib and thiazolidinediones.

The sequences referenced herein have been deposited at the dbSNP database of the NCBI (www.ncbi.nlm.nih.gov/snp).

As used herein, an “allelic variation” refers to a variation in the nucleic acid and typically primary amino acid sequence of a gene in one or more alleles in a subject, such as a human patient. Allelic variations include single or multiple nucleic acid and amino acid substitutions, additions or deletions that have any one of a number of effect on protein expression, including without limitation: promoter activity that regulates transcription, frame-shift, early protein termination, protein mis-folding, altered protein processing, destruction (or enhancement) of active sites or binding sites of a protein, mis-splicing of an mRNA or any other property of a nucleic acid or protein that effects the expression and/or function of the final gene products.

A large number of methods, including high-throughput methods, are available for detection of SNPs and/or other allelic variations, for example, and without limitation, the PCR and Restriction Fragment Length Polymorphisms methods described in the Examples below. In one embodiment, DNA from a sample is sequenced (re-sequenced) by any method to identify a SNP or small allelic variation. A large variety of re-sequencing methods are known in the art, including high-throughput methods. Amplification-based methods also are available to identify allelic variations, such as SNPs, including, without limitation: PCR, reverse transcriptase PCR (RT-PCR), isothermic amplification, nucleic acid sequence based amplification (NASBA), 5' fluorescence nuclease assay (for example TAQMAN assay), molecular beacon assay and rolling-circle amplification. Other methods, such as Restriction Fragment Length Polymorphisms RFLP, also may be employed—as is appropriate and effective to identify variant allele(s). Assays may be multiplexed, meaning two or more reactions are carried out simultaneously in the same physical location, such as in the same tube or position on an array—so long as the reaction products of the multiplexed reactions can be distinguished. As a non-limiting example, TAQMAN or molecular beacon assays can be multiplexed by use of and by monitoring of accumulation or depletion of two different fluorochromes corresponding to two different sequence-specific probes. In most cases, the appropriate method is dictated by personal choice and experience, equipment and reagents on hand, the need for high-throughput and/or multiplexed methods, cost, accuracy of the method, and the skill level of technicians running the assay. Design and implementation of those techniques are broadly-known and are well within the abilities of those of average skill in the art.

In the implementation of the methods provided herein, and in particular in respect of the screening step, an array may be utilized. Arrays are particularly useful in implementing high-throughput assays. The array typically comprises one or more reagents, for example and without limitation, nucleic acid primers and/or probes, for identifying in a nucleic acid sample from a subject the occurrence of an allelic variation corresponding to one or more single nucleotide polymorphisms identified herein.

A sixth aspect of the present disclosure provides a solid support substrate having an array of affinity molecules deposited thereon, wherein the molecules have affinity for and/or hybridize to, one or more polynucleotides comprising

single nucleotide polymorphisms identified herein as rs6921438, rs4416670, rs6993770, rs10738760, rs16873365, rs16873402, rs16873291, rs2375980, rs910611 and/or wherein the molecules have affinity for and/or hybridize to one or more of the genes selected from VLDLR, LRP12, ZFPM2 and KCNV2. The molecules are preferably polynucleotides, and are preferably the molecules are covalently attached to the substrate.

As used herein, the term “array” refers to reagents for facilitating identification of allelic variations in a gene located at two or more identifiable locations. In one embodiment, an array is an apparatus having two or more discrete, identifiable reaction chambers, such as, without limitation a 96-well dish, in which reactions comprising identified constituents are performed. In an exemplary embodiment, two or more nucleic acid primers or probes are immobilized onto a substrate in a spatially addressable manner so that each individual primer or probe is located at a different and (addressable) identifiable location on the substrate. Substrates include, without limitation, multi-well plates, silicon chips and beads. In one embodiment, the array comprises two or more sets of beads, with each bead set having an identifiable marker, such as a quantum dot or fluorescent tag, so that the beads are individually identifiable using, for example and without limitation, a flow cytometer. In one embodiment, in the context of the present disclosure, an array may be a multi-well plate containing two or more well reaction chambers with primers for amplifying DNA to identify SNPs or probes for binding specific sequences. As such, reagents, such as probes and primers may be bound or otherwise deposited onto or into specific locations on an array. Reagents may be in any suitable form, including, without limitation: in solution, dried, lyophilized or glassified. Useful array technologies include, for example and without limitation an Affymetrix GeneChip® Array, for example, GeneChip® CustomSeq® Resequencing Arrays (commercially available from Affymetrix Inc. of Santa Clara, Calif.) and like technologies. Informatics and/or statistical software or other computer-implemented processes for analyzing array data and/or identifying genetic risk factors from data obtained from a patient sample, are known in the art.

According to various methods of the present disclosure, the screening step produces an output signal which identifies the presence or absence of a specific allelic variant or gene expression level, or identifies an appropriate course of action. The course of action resulting from the signal output may, for example, be to administer or not administer a VEGF-based therapy. The output signal may take any appropriate form. It may, for example, be an audio or visual output signal, or may involve a light output, or a written communication.

The present disclosure is exemplified by reference to the following non-limiting examples. Example 1 describes the identification of the SNPs of the disclosure.

### Example 1

#### Study Populations

##### 1. The Framingham Heart Study (FHS)

The FHS, initiated in 1948, is a three-generation, community-based, prospective cohort study conducted in Framingham, Mass., USA. Serum VEGF levels were measured in third generation cohort participants (2002-2005) and genome-wide genotyping was performed on these individuals at Affymetrix (Santa Clara, Calif.) through an

NHLBI funded SNP-Health Association Resource (SHARE) project. We chose not to include participants with cardiovascular disease, as the latter may influence VEGF levels. After excluding participants who had prevalent cardiovascular disease, which may influence their VEGF levels, or failed to meet quality control standards, 3,527 participants were enrolled.

### 2. The STANISLAS Family Study (SFS)

The SFS is a 10-year longitudinal survey involving 1,006 volunteer families from Vandoeuvre-lès-Nancy, France, whose members were free of chronic disease (cardiovascular or cancer) between 1993-1995. Plasma VEGF levels were measured at the second examination cycle (1998-2000) in a randomly selected sub-sample; of these 859 persons from 217 families, who also had DNA and met genotyping quality control criteria, were included.

### 3. Prospective Investigation of the Vasculature in Uppsala Seniors (PIVUS) Study

The PIVUS study is a population-based study that enrolled 1,016 70-year old individuals living in the community of Uppsala, Sweden (2001-2004). Of these, 999 persons provided DNA for genetic studies and after exclusions for prevalent cardiovascular disease and inadequate genotyping quality, 868 participants were eligible. Characteristics of the 5,273 study participants are presented in Table 1.

TABLE 1

Characteristics	FHS	SFS <sup>†</sup>	PIVUS Study
Number of participants	3,527	859	868
Mean circulating VEGF level (ng/L), median (IQR) *	280 (294.7)	27.4 (28.2)	187.5 (210.6)
Mean age (SD) at VEGF measurement, mean (SD)	40.0 (8.7)	29.83 (14.5)	70.2 (0.2)
Women (%)	1890 (53.2)	428 (49.8)	454 (52.3)
Cardiovascular risk factor at VEGF measurement			
Systolic blood pressure, mean (SD)	116.7 (14.0)	120.3 (12.8)	149.6 (22.7)
Hypertension (%)	561 (15.9)	23 (2.7)	606 (69.8)
Diabetes mellitus (%)	89 (2.5)	0	68 (7.8)
Current smoker (%)	544 (15.3)	188 (21.9)	93 (10.7)
Central obesity (%)	1315 (37.2)	37 (44.3)	266 (30.6)
Metabolic syndrome (%)	693 (19.6)	19 (2.2)	198 (22.8)

IQR: Inter-Quartile Range; SD: Standard Deviation;

\* Serum levels for the FHS and the PIVUS study, and plasma levels for the SFS;

<sup>†</sup>by design, SFS participants were free of chronic disorders (cardiovascular or cancer) and had no personal history of cardiovascular disease at the time of inclusion (VEGF levels and covariates for the present analysis were measured during the second examination cycle in 1998-2000); all individuals with CVD (cardiovascular disease), defined in the FHS as presence of stroke, congestive heart failure, coronary heart disease or intermittent claudication, were excluded before analyses in FHS and PIVUS.

### Laboratory Measurements of VEGF Levels

VEGF levels were measured in serum for the FHS and PIVUS and plasma for the SFS. In all 3 studies venous blood samples were drawn after an overnight fast, immediately centrifuged and stored appropriately (at  $-80^{\circ}\text{C}$ . in FHS and PIVUS and at  $-196^{\circ}\text{C}$ . in liquid nitrogen in SFS) until VEGF measurements were undertaken. At FHS, serum VEGF was measured using a commercial ELISA assay (R&D Inc.). In SFS and PIVUS plasma VEGF and serum VEGF quantification respectively was performed by Randox Ltd (Crumlin, UK), using a biochip array analyzer (Evidence®). In all studies both diffusible VEGF isoforms (VEGF<sub>121</sub> and VEGF<sub>165</sub>) were detected.

The average inter-assay coefficients of variation were 2.1% for serum VEGF in the FHS, less than 9% in the SFS and less than 15% in the PIVUS study.

Since serum VEGF had been measured in the FHS and PIVUS and plasma for VEGF in the SFS, we checked the correlation between the 2 types of specimens. VEGF was measured in a subset (n=18) of matched plasma and serum samples from the SFS. Plasma VEGF was lower ( $42\pm 28$  ng/L, mean $\pm$ SD) than serum VEGF ( $361\pm 223$  ng/L); There was a strong correlation between plasma and serum VEGF ( $r=0.76$ ,  $p=0.0002$ ) which strengthens our study.

### Genotyping

#### 1. FHS

Genome-wide genotyping in the FHS was performed on the Affymetrix GeneChip Human Mapping 500K Array Set® and 50K Human Gene Focused Panel®. The set of genotyped input SNPs used for imputation was selected based on their highest quality GWA data. From a total of 534,982 genotyped autosomal SNPs in FHS, we used 378,163 SNPs in the imputation after filtering out 15,586 SNPs for Hardy-Weinberg disequilibrium ( $p<1\times 10^{-6}$ ), 64,511 SNPs for missingness $>0.03$ , 45,361 SNPs for a test of differential missingness yielding a  $p<1\times 10^{-9}$  (mishap test in PLINK, <http://pngu.mgh.harvard.edu/purcell/plink/>), 4,857 SNPs for  $>100$  Mendel errors, 67,269 SNPs for a minor allele frequency $<0.01$ , 2 SNPs due to strandedness issues upon merging data with HapMap, and a further 13,394 SNPs because they were not present on HapMap. We used the Markov Chain Haplotyping (MaCH) package (<http://www.sph.umich.edu/csg/abecasis/MACH>, version 1.0.15 software) and imputed to the plus strand of NCBI build 36, HapMap release #22. For each imputed SNP, imputation quality was estimated as the ratio of the empirically observed dosage variance to the expected binomial dosage variance. After quality control and filtering, FHS had either genotyped or imputed data for 2,540,223 autosomal SNPs. From a total of 10,886 genotyped SNPs on the X chromosome, we used 7,795 SNPs in the imputation after filtering out 3,091 SNPs for Hardy-Weinberg  $p<1\times 10^{-6}$  (n=159), missingness $>0.03$  (n=450), minor allele frequency $<0.01$  (n=1851), male heterozygote count $>45$  (n=12), and a further 619 SNPs because they were not present on HapMap. We used the IMPUTE package (<https://mathgen.stats.ox.ac.uk/impute/impute.html>, version 0.5.0) and imputed to the plus strand of NCBI Build 35, Hapmap release #21.

#### 2. SFS

The SNPs were genotyped by Genoscreen® (<http://genoscreen.fr>) using a Sequenom® iPLEX Gold assay—Medium Throughput Genotyping Technology.

#### 3. PIVUS Study

The SNPs were genotyped as part of a 96-plex assay at the SNP technology platform in Uppsala University (<http://www.genotyping.se/>) using the Illumina BeadXpress system from Illumina Inc. Genotyping calls were done with Illumina BeadStudio software.

### Statistics

VEGF levels were natural log-transformed to normalize their distribution.

#### Genome-Wide Association Analysis in the FHS

A linear mixed effects model accounting for familial relatedness was used to evaluate the association of each SNP with VEGF levels. An additive genetic model with one degree of freedom was used. In a first step (Model A), analyses were adjusted for age, sex, and the ninth principal component.

In a second step designed to explore potential mechanisms, we additionally adjusted our most significant associations for covariates previously found to be associated with serum VEGF levels: compared to Model A, Model B was additionally adjusted for hypertension; model C for

smoking; model D for central obesity and model E for the presence of a metabolic syndrome.

Genetic Association Study in the SFS and the PIVUS Study

In order to confirm our findings in the FHS, we genotyped 25 SNPs in two independent samples. To select a parsimonious number of SNPs for replication we used criteria of strength of association (p-value), whether the SNP was genotyped or imputed, linkage disequilibrium (LD) between SNPs and functionality.

From all SNPs associated with VEGF levels at a p-value <  $5 \times 10^{-8}$  in the discovery cohort, we excluded SNPs with minor allele frequencies (MAF) < 0.05 as well as those imputed SNPs with low imputation quality (ratio of the empirically observed dosage variance to the expected binomial dosage variance < 0.6). The remaining SNPs were grouped by "bins", each bin comprising SNPs that are in very strong linkage disequilibrium (LD) with each other, i.e. with an  $r^2 > 0.8$  with the most significant SNP in the bin. Within each bin we selected one SNP for replication (except for the bin with the most significant associations where 2 SNPs were selected). Typically, we selected the SNP with the lowest p-value within each bin. In 6 bins a SNP with a slightly higher p-value was chosen either because this SNP had been directly genotyped in the discovery cohort, whereas the SNP with the lowest p-value in the bin had been imputed (rs1776721 and rs1886979) or because there were stronger arguments for functionality for the SNP with the slightly higher p-value (rs16873291, rs1349319, rs6475920 and rs10967492). A linear regression model using the same covariates and analytic strategy as in the FHS was implemented.

Joint Analysis of the FHS, SFS and PIVUS Study

For SNPs that were successfully genotyped in the SFS and the PIVUS study we performed a meta-analysis of the SNP-phenotype associations, using a fixed effects inverse-variance meta-analysis technique for the combination of results from the FHS and the PIVUS study (which had both measured VEGF levels in the serum) and an effective sample size weighted meta-analysis for the combination of results from all three studies, to account for the different scales of VEGF levels in serum and plasma.

Genetic Score

The methods used for computing a genetic score are detailed below. The phenotypic variance explained by this genetic score was separately calculated in the FHS, the SFS and the PIVUS study, using regression models that included age and sex as covariates.

Step 1:

We selected SNPs with independent effects by running a conditional GWAS. This was done in a forward stepwise fashion. First we ran a GWAS adjusting for age, gender, the ninth principal component and the most significantly associated SNP (rs6921438). We then ran a GWAS additionally adjusting for the most significantly associated SNP in the aforementioned conditional GWAS. This process was repeated, by adding the most significantly associated SNP as a new covariate to the regression model, until all SNPs independently associated with VEGF level at a p-value <  $5 \times 10^{-8}$  were selected. All selected independent SNPs with a minor allele frequency > 5% were used to compute the genetic score (see Table 2). In the PIVUS study, as rs6921438 genotypes were not available, rs4513773 was used instead to compute the genetic score ( $r^2$  with rs6921438 = 0.90)

Step 2:

Genotypes for the SNPs selected in step 1 were coded as 0, 1 or 2 for genotyped SNPs (according to the number of minor alleles) and the imputed allele dosage was used for imputed SNPs.

To compute the genetic score the genotype value was weighted by the effect size estimate from the GWAS (see Table 2):

$$\text{Risk Score} = \text{SNP1\_estimate} * \text{SNP1\_genotype} + \text{SNP2\_estimate} * \text{SNP2\_genotype} + \text{SNP3\_estimate} * \text{SNP3\_genotype} + \text{SNP4\_estimate} * \text{SNP4\_genotype}$$

Step 3:

We estimated the proportion of phenotype variance explained by each SNP incorporated in the risk score ( $h_q^2$ ; see Table 2);  $h_q^2$  was computed as follows, using the GWAF R-package:

$$h_q^2 = \max\left(0, \frac{\sigma_{G,null}^2 + \sigma_{e,null}^2 - \sigma_{G,full}^2 - \sigma_{e,full}^2}{\text{Var}(y)}\right)$$

wherein:

Var(y) = total phenotypic variance;

$\sigma_{G,null}^2$  and  $\sigma_{e,null}^2$  = the polygenic variance and error variance when modeling without the tested SNP; and

$\sigma_{G,full}^2$  and  $\sigma_{e,full}^2$  = the polygenic variance and error variance when modeling with the tested SNP.

VEGF Gene Expression Analysis in Peripheral Blood Mononuclear Cells (PBMCs)

Sample preparation and quantification of the PBMC messenger RNA (mRNA) of VEGF spliced forms. Two-hundred and twenty samples from the SFS were randomly selected for inclusion in the PBMCs transcriptomic study. Fresh whole blood (10 mL) was collected by standardized venipuncture in EDTA tubes (Vacutainer™; Becton Dickinson, NJ, USA). PBMCs were isolated by centrifugation on a density gradient of Ficoll (Ficoll-Paque™ PLUS; Amersham BioSciences) and stored at  $-80^\circ \text{C}$ . until RNA extraction according to a well-validated protocol, with high recovery of lymphocyte (97.5%). Total RNA was subsequently extracted with the MagNaPure automate, using the MagNA Pure LC RNA HP isolation kit and RNA HP Blood External lysis protocol (Roche Diagnostics, France). Reverse transcription of total RNA was performed using 200 units of M-MuLV Reverse Transcriptase with 0.25  $\mu\text{g}$  of oligos(dt) (Promega, France) according to a previous described protocol. Quantification of the transcripts coding for the VEGF<sub>121</sub> and VEGF<sub>165</sub> isoforms, and the beta 2 microglobulin (B2M) control gene, was performed using TaqMan® and LightCycler technologies (LC TaqMan Master kit Roche Diagnostics, France). All experiments were performed in duplicate. The detection level for each transcript was between 1 and 10 copies for both transcripts and for B2M. RT-PCR optimization and specificity of RT-PCR products were examined using SYBR® Green technology (LC FastStart DNA Master<sup>PLUS</sup> SYBR Green I kit, Roche Diagnostic, France), melting curves analysis and agarose gel electrophoresis of the PCR amplicons. Primers and probes were designed to specifically amplify the spliced forms of VEGF based on their splicing sites with specific reverse primers or hydrolyzation probes spanning the variant specific exon boundaries, which also avoids amplification of contaminating genomic DNA. Hydrolyzation probes were labeled with the reporter dye FAM (6-carboxy-fluorescein phosphoramidite) at the 5' end and the quencher dye TAMRA (5-carboxyl-tetramethyl-rhodamine) at the 3' end.

For all assays, intra- and inter-run variability were 11% and 5% respectively. PCR products for each VEGF mRNA spliced variant amplification were purified with a PCR purification kit (QiaQuick, Qiagen, France). The product concentrations were measured in a spectrophotometer, the molecule concentrations were calculated, and a standard curve was generated for each transcript using serial dilutions of products ranging from 1 or 10 to  $10^7$  molecules/ $\mu\text{L}$ . The copy number of unknown samples was calculated by setting their PCR cycle number (Crossing Point: CP) to the standard curve and normalized to the housekeeping B2M gene. Results are presented as copies of the target gene product per  $10^5$  copies of B2M. Primer efficiencies were calculated according to the equation  $E=10[-1/\text{slope}]$ . All investigated transcripts had real-time PCR efficiency rates above 1.9.

#### PBMCs VEGF Protein Measurements

PBMC VEGF (121 and 165) protein quantification was performed by Randox Ltd (Crumlin, UK), with a biochip array analyzer (Evidence®) using a high sensitivity kit as previously described.<sup>7</sup> PBMC VEGF concentrations were log 10-transformed in all analyses in order to improve normality, were adjusted for the effect of between-run variation and regressed on mean values of all samples measured in each run. Grubbs' test was applied for detection of the extreme values in the data (log transformed VEGF) and there were no outliers at the 5% level. The average inter-assay coefficient of variation was 5.7%.

#### Statistical Analysis

A linear mixed effects model that accounts for within family correlation was used to evaluate the association of each of the SNPs successfully genotyped in the SFS with each of the two transcript levels (VEGF<sub>121</sub> and VEGF<sub>165</sub>) and with natural log-transformed PBMC VEGF concentration, assuming an additive genetic model. These analyses were adjusted for age and sex.

#### Biological Pathway Analysis

Genes located close to associated SNPs were investigated for relevant networks by the Ingenuity Pathway Analysis (IPA) software (Ingenuity Systems, www.ingenuity.com). To build networks, IPA queries the Ingenuity Pathways Knowledge Base for biological interactions between identified "focus genes", in this case genes close to SNPs significantly associated with circulating VEGF levels in the GWAS, and all other gene objects stored in the knowledge base. It then generates a set of networks with a maximum network size of 35 genes. An underlying assumption is that highly-interconnected networks are likely to represent significant biological function, thus IPA optimizes for triangular relationships between genes, favoring denser networks over more sparsely connected ones. Networks are displayed graphically as "nodes" (corresponding to genes or gene products) and the biological relationships between the nodes, referred to as "edges". IPA also computes a score, representing the  $-\log_{10}$  (p-value), where the p-value is the

probability of finding  $f$  or more focus genes in a set of  $n$  genes randomly selected. If there are 'n' genes in the network and  $f$  of them are focus genes, the p-value is the probability of finding  $f$  or more focus genes in a set of 'n' genes randomly selected from the Global Molecular Network. It is calculated using Fisher's exact test.

#### GWAS of VEGF Levels in the FHS

The quantile-quantile (QQ) plot showed an excess of extreme p-values but no evidence of systematic inflation of the genomic control inflation factor ( $\lambda=1.02$ ) (see FIG. 1). The genome-wide plot of p-values for the individual SNPs against their genomic position is shown in FIG. 2. A total of 140 SNPs cleared the threshold for genome-wide significance at  $5 \times 10^{-8}$ . These are shown in FIGS. 6A-6E.

The 140 SNPs that cleared the threshold for genome-wide significance were located in three chromosomal regions: 6p21.1, 8q23.1, 9p24.2. These are shown in FIG. 7.

The most significant association was found with rs6921438 on chromosome 6p21.1 ( $p=6.11 \times 10^{-506}$ ), at 171 kb downstream of the VEGF gene, and close to the mitochondrial ribosomal protein L14 gene (MRPL14) and the MCG45491 gene (C6orf223), encoding an uncharacterized protein. Sixty-seven other SNPs on chromosome 6p21.1 were also associated with VEGF levels at  $p < 5 \times 10^{-8}$  (see FIG. 3A). When running a conditional GWAS adjusting for rs6921438, one other SNP in 6p21.1 (rs4416670) still yielded a genome-wide significant association, suggesting that two variants in this region independently modulate VEGF levels. In the 8q23.1 region the SNP yielding the most significant association with VEGF levels (rs6993770,  $p=2.50 \times 10^{-16}$ ) is located in the zinc finger protein, multitype 2 (ZFP2) gene and 980.4 kb away from the low-density lipoprotein receptor-related protein 12 gene (LRP12). Forty-three SNPs in LD with rs6993770 were also associated with VEGF levels at  $p < 5 \times 10^{-8}$  (see FIG. 3B). A conditional GWAS adjusting for rs6993770, rs6921438 and rs4416670 did not yield any other genome-wide significant association in chromosome 8q23.1. The most significant association on 9p24.2 was observed with rs10738760 ( $p=1.96 \times 10^{-34}$ ), located close to the very low density lipoprotein receptor (VLDLR) and potassium voltage-gated channel subfamily V, member 2 (KCNV2) genes. Twenty-nine SNPs in LD with rs10738760 were also associated with VEGF levels at  $p < 5 \times 10^{-8}$  (FIG. 3C). None reached genome-wide significance in a conditional GWAS adjusted for rs6921438, rs4416670, rs6993770 and rs10738760.

A genetic score including the four SNPs yielding genome-wide significant associations with VEGF levels in the conditional GWAS was computed. Results of the main and conditional GWAS within the Framingham Heart Study sample for the SNPs retained in the genetic score calculation are shown in Table 2. This score explained 47.6% of serum VEGF variability ( $p=2.19 \times 10^{-644}$ ).

The genetic score for a single SNP, rs6921438, explains 41.2% of the phenotypic variation in FHS (see FIG. 4).

TABLE 2

SNP	chr	position	CA	CAF	Estimate in main GWAS*	SE in	p in		$h^2_g$ %
						main GWAS*	p in main GWAS*	conditional GWAS†	
rs6921438	6	44033585	G	0.51	0.7199	0.0149	$<5 \times 10^{-324}$	$<5 \times 10^{-324}$	41.19
rs10738760	9	2681186	A	0.49	0.2812	0.0230	$1.96 \times 10^{-34}$	$3.78 \times 10^{-47}$	4.97

TABLE 2-continued

SNP	chr	position	CA	CAF	Estimate in main GWAS*	SE in main GWAS*	p in main GWAS*	p in conditional GWAS†	$h^2_g$ %
rs6993770	8	106650704	T	0.32	-0.1667	0.0203	$2.50 \times 10^{-16}$	$5.45 \times 10^{-30}$	2.03
rs4416670	6	44058431	T	0.55	0.1342	0.0190	$1.47 \times 10^{-12}$	$4.79 \times 10^{-9}$	1.46

CA: coded allele

CAF: coded allele frequency;

Chr: chromosome;

GWAS: genome-wide association study;

 $h^2_g$ : percentage of phenotypic variance explained;

SE: standard error;

\*adjusted for age, sex, and the ninth principal component;

†with all four SNPs in the same model, additionally adjusted for age, sex, and the ninth principal component.

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### Replication Studies

We sought to replicate our most significant results in two independent cohorts. Of the 25 SNPs selected for replication, 24 were successfully genotyped in the SFS and 20 in the PIVUS study, as shown in FIG. 7. Of these, 17 and 20 respectively reached nominal significance in association with VEGF levels, with the same direction of effect (FIG. 7). When meta-analyzing the results of the FHS and the PIVUS study, which both used serum VEGF levels, for the 19 SNPs

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220 SFS participants. The association of VEGF mRNA levels with the 24 SNPs successfully genotyped in the SFS was assessed.

At the nominal significance level, 1 SNP on chromosome 6p21.1, 4 SNPs on chromosome 8q23.1 and 1 SNP on chromosome 9p24.2 were associated with VEGF<sub>121</sub> mRNA levels (see Table 5).

TABLE 5

Phenotype	SNP	Chr	position	CA	CAF	beta†	SE	p	$h^2_g$ %
mRNA_121	rs16873365	8	106627411	T	0.22	22.71	7.22	0.002	4.73
mRNA_121	rs16873402	8	106658423	T	0.33	12.15	5.10	0.017	2.84
mRNA_121	rs6993770	8	106650704	T	0.32	12.06	5.23	0.021	2.82
mRNA_121	rs16873291	8	106597206	T	0.31	11.95	5.37	0.026	2.47
mRNA_121	rs2375980	9	2682622	G	0.42	10.15	4.75	0.032	2.03
mRNA_121	rs910611	6	44058829	C	0.08	-19.47	9.49	0.040	2.13

\*log-transformed;

†effect estimate for the minor allele;

CAF: Coded Allele Frequency;

Chr: chromosome;

 $h^2_g$ : variance explained;

SE: standard error

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genotyped in both studies, all 19 SNPs were associated with VEGF levels at  $p < 0.05$  (FIG. 7). The joint meta-analysis of results from all three studies, using an effective sample size weighted meta-analysis, is displayed in FIG. 7. There was statistically significant heterogeneity between studies for a few but not all SNPs in each locus, due to differences in effect size, but not in direction of effects. Table 3 shows the test of heterogeneity between studies in the meta-analyses combining discovery and replication cohorts. The genetic score explained 16.6% ( $p = 1.75 \times 10^{-36}$ ) of observed plasma VEGF variability in the SFS and 48.4% ( $p = 3.31 \times 10^{-180}$ ) of observed serum VEGF variability in the PIVUS study.

The observed associations remained unchanged in each of the three cohorts after adjusting for hypertension, current smoking, central obesity and metabolic syndrome. Table 4 shows the secondary genetic association analysis adjusting for clinical covariates previously found to be associated with VEGF levels. All analyses were adjusted for age, sex, and principal components. Model B was additionally adjusted for hypertension; model C for smoking; model D for central obesity; model E for the presence of a metabolic syndrome. VEGF Gene Expression Analysis

In order to better characterize the functional role of the SNPs identified in the GWAS we quantified mRNA expression of the two splice variants corresponding to the diffusible isoforms of VEGF, VEGF<sub>121</sub> and VEGF<sub>165</sub>, in PBMCs of

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### Biological Pathway Analysis

Using the Ingenuity Pathway Analysis software (IPA, Ingenuity Systems, www.ingenuity.com) we explored functional relationships between VEGF and the genes closest to the SNPs on chromosome 8q23.1 and 9p24.2 that were significantly associated with circulating VEGF levels. In each case we selected the genes closest to the identified SNPs, as in FIG. 7, to identify plausible biological pathways. We selected five focus genes: VEGF; ZFPM2; LRP12; VLDLR; and KCNV2. The IPA network analysis identified relationships among three of these five focus genes (VEGF, ZFPM2 and VLDLR) as part of a larger network of 35 genes. The probability of finding 3 or more focus genes in a set of 35 genes randomly selected from the Global Molecular Network was  $p = 10^{-8}$ , suggesting that the presence of three of our five focus genes in this network was unlikely to occur by chance. FIG. 5 shows a subset of this network, including only interactions between VEGF and the two other focus genes in the network, with 2 or fewer intermediate nodes.

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### Principal Findings

In this first GWAS of circulating VEGF levels undertaken in 3,527 community individuals of European descent, we identified novel genetic associations: 140 SNPs reached genome-wide significance. Of these, 4 SNPs were independently associated with VEGF levels (rs6921438 and rs4416670 on chromosome 6p21.1, rs6993770 on chromo-

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some 8q23.1 and rs10738760 on chromosome 9p24.2). We found evidence of replication for selected SNPs in 1,727 individuals of European descent from two independent community-based samples. The SNPs are located close to the VEGF and MRPL14 genes (chromosome 6p21.1), within the ZFPM2 gene (chromosome 8q23.1), and between the VLDLR and KCNV2 genes (chromosome 9p24.2). In a subset of participants we found that 6 of 25 selected SNPs yielding genome-wide significant associations with circulating VEGF levels were also associated with VEGF mRNA levels (VEGF<sub>121</sub> splice variant) in PBMCs.

Using a hypothesis-free genome-wide approach, the present study revealed novel associations with 140 SNPs. Of these, 68 SNPs are located on chromosome 6 approximately 150 kb downstream from the 3' end of the VEGF gene, far from previously tested candidate SNPs. None of the SNPs that reached genome-wide significance in our analysis, on chromosome 6p21.1, 8q23.1 and 9p24.2, had been examined previously in relation with circulating VEGF levels.

The data support that six of the SNPs associated with circulating VEGF levels in our GWAS also modulate the expression of the VEGF splice variant in PBMCs of community-based persons. The diffusible VEGF isoforms, VEGF and VEGF<sub>121</sub>, are released by a variety of tumor and normal cells, including PBMCs. VEGF lacks a heparin-binding domain and has a higher migration but lower mitogenic potency than VEGF.

Potential Mechanisms Mediating Observed Genetic Associations

The data demonstrate that almost half the inherited component of circulating VEGF levels is explained by genetic variants located downstream from the VEGF gene on chromosome 6p21.1. The conditional GWAS demonstrates that this region may harbor at least two distinct loci that are independently associated with circulating VEGF levels. Although located relatively far from the VEGF gene, results from our transcriptomic analysis indicate that this region could indeed contain functional variants modulating VEGF gene expression.

Genome-wide significant associations with circulating VEGF levels were also identified for SNPs located on chromosome 8q23.1 and 9p24.2. Although these trans-effects explain a much smaller proportion of the heritability of VEGF levels, they provide important clues about the pathways involved in the regulation of VEGF expression. The SNPs on chromosome 8q23.1 are located in introns 4 and 5 of the ZFPM2 gene. This gene encodes a widely expressed member of the Friend of GATA family of transcription factors that modulate the activity of the GATA family proteins, which are important regulators of embryogenesis and also seem to play a significant role in endothelial cell biology. The second closest gene to the SNPs identified on chromosome 8q23.1 is LRP12, encoding a low-density lipoprotein receptor-related protein that interacts with proteins related to signal transduction pathways and is differentially expressed in many cancer cells. The SNPs on chromosome 9p24.2 are located between the VLDLR and

KCNV2 genes. VLDLR encodes a lipoprotein receptor involved in the metabolism of apolipoprotein-E-containing triacylglycerol-rich lipoproteins. Like VEGF, VLDLR appears to modify the risk of developing age-related macular degeneration, and data show that VLDLR could play a central role in a network of interacting angiogenic genes activated in response to hypoxia. KCNV2 encodes a member of the potassium voltage-gated channel subfamily V involved in regulation of neurotransmitter release, neuronal excitability and heart rate. The in silico biological pathway analysis suggests that ZFPM2 and VLDLR are candidate genes that underlie the observed SNP associations with circulating VEGF levels. Further research may explore the mechanisms underlying the associations of cis- and trans-acting genetic variants with circulating VEGF levels, such as modulation of gene expression, differential splicing or mRNA degradation.

The findings from this first GWAS of circulating VEGF levels emphasize the importance of screening for genetic variation modulating biomarker levels not only within and in close proximity to the gene encoding the protein under investigation, but also in more distant potentially regulatory regions, including on other chromosomes. The strength of the observed associations and the fact that we were able to replicate our findings in two independent cohorts support these associations. This is further supported by the association of several of these genetic variants with VEGF gene expression in PBMCs.

TABLE 3

SNP	Chr	Heterogeneity	
		Inverse variance weighted meta-analysis (FHS + PIVUS)	Effective sample size weighted meta-analysis (FHS + SFS + PIVUS)
rs6921438	6	1	$5.50 \times 10^{-21}$
rs4513773	6	0.52	0.19
rs9472159	6	$5.70 \times 10^{-3}$	$6.07 \times 10^{-18}$
rs9369434	6	$4.32 \times 10^{-15}$	$7.74 \times 10^{-26}$
rs1776717	6	0.18	0.69
rs1776721	6	0.31	0.068
rs1886979	6	0.90	0.20
rs9472155	6	0.20	0.056
rs844294	6	0.71	0.14
rs4416670	6	0.10	0.23
rs910611	6	0.52	0.13
rs6993770	8	0.087	0.099
rs16873402	8	0.033	0.011
rs16873365	8	0.052	0.022
rs7013321	8	1	0.41
rs6993696	8	0.67	0.39
rs16873291	8	0.069	0.098
rs1349319	8	0.66	0.70
rs10738760	9	0.14	$2.20 \times 10^{-3}$
rs6475920	9	0.78	$7.20 \times 10^{-3}$
rs4741756	9	0.11	$9.84 \times 10^{-4}$
rs2375980	9	0.44	0.018
rs10122587	9	1	0.015
rs10967492	9	1	$5.79 \times 10^{-3}$
rs10967470	9	1	0.016

TABLE 4

SNPID	Chr	Position	p (FHS)	p (PIVUS)	p (SFS)	Meta-p (FHS + PIVUS)*	Meta-p (all)†
Model B							
rs6921438	6	44033585	$1.72 \times 10^{-506}$	NA	$1.84 \times 10^{-39}$	$1.72 \times 10^{-506}$	$1.06 \times 10^{-524}$
rs4513773	6	44033504	$1.58 \times 10^{-482}$	$7.98 \times 10^{-139}$	NA	$4.41 \times 10^{-619}$	$1.28 \times 10^{-584}$
rs9472159	6	44027673	$2.89 \times 10^{-452}$	$2.90 \times 10^{-109}$	$3.58 \times 10^{-35}$	$8.76 \times 10^{-558}$	$7.76 \times 10^{-553}$

TABLE 4-continued

SNPID	Chr	Position	p (FHS)	p (PIVUS)	p (SFS)	Meta-p (FHS + PIVUS)*	Meta-p (all)†
rs9369434	6	44026385	$8.70 \times 10^{-443}$	$3.02 \times 10^{-63}$	$5.81 \times 10^{-28}$	$1.54 \times 10^{-490}$	$2.23 \times 10^{-496}$
rs1776717	6	44059314	$1.23 \times 10^{-19}$	$2.27 \times 10^{-4}$	$8.96 \times 10^{-6}$	$2.59 \times 10^{-22}$	$8.45 \times 10^{-27}$
rs1776721	6	43998961	$1.17 \times 10^{-19}$	$4.34 \times 10^{-8}$	0.018	$5.02 \times 10^{-26}$	$3.12 \times 10^{-26}$
rs1886979	6	44012879	$3.23 \times 10^{-19}$	$2.71 \times 10^{-6}$	0.013	$4.82 \times 10^{-24}$	$1.29 \times 10^{-24}$
rs9472155	6	44005705	$4.98 \times 10^{-19}$	$4.83 \times 10^{-9}$	0.014	$3.39 \times 10^{-26}$	$1.68 \times 10^{-26}$
rs844294	6	44008685	$1.34 \times 10^{-14}$	$1.95 \times 10^{-5}$	0.087	$1.41 \times 10^{-18}$	$2.50 \times 10^{-18}$
rs4416670	6	44058431	$2.04 \times 10^{-12}$	0.1	$2.79 \times 10^{-4}$	$1.95 \times 10^{-12}$	$2.81 \times 10^{-15}$
rs910611	6	44058829	$4.77 \times 10^{-10}$	$4.72 \times 10^{-6}$	0.11	$1.43 \times 10^{-14}$	$2.99 \times 10^{-14}$
rs6993770	8	106650704	$2.03 \times 10^{-16}$	$3.61 \times 10^{-8}$	0.016	$1.94 \times 10^{-22}$	$2.96 \times 10^{-23}$
rs16873402	8	106658423	$1.45 \times 10^{-14}$	$1.16 \times 10^{-8}$	0.14	$9.09 \times 10^{-21}$	$3.86 \times 10^{-20}$
rs16873365	8	106627411	$6.93 \times 10^{-12}$	$2.10 \times 10^{-6}$	0.37	$5.14 \times 10^{-16}$	$2.91 \times 10^{-15}$
rs7013321	8	106662734	$4.66 \times 10^{-12}$	NA	0.013	$4.66 \times 10^{-12}$	$2.84 \times 10^{-13}$
rs6993696	8	106650460	$8.83 \times 10^{-12}$	$1.57 \times 10^{-4}$	0.040	$6.67 \times 10^{-15}$	$1.82 \times 10^{-15}$
rs16873291	8	106597206	$5.43 \times 10^{-11}$	$1.42 \times 10^{-6}$	0.061	$1.76 \times 10^{-15}$	$6.60 \times 10^{-16}$
rs1349319	8	106625810	$2.93 \times 10^{-8}$	$1.73 \times 10^{-3}$	0.040	$2.03 \times 10^{-10}$	$3.05 \times 10^{-11}$
rs10738760	9	2681186	$1.17 \times 10^{-34}$	$3.24 \times 10^{-9}$	0.035	$6.36 \times 10^{-42}$	$2.26 \times 10^{-40}$
rs6475920	9	2663933	$2.23 \times 10^{-32}$	$1.46 \times 10^{-8}$	0.022	$2.21 \times 10^{-39}$	$3.30 \times 10^{-38}$
rs4741756	9	2658187	$2.29 \times 10^{-31}$	$7.05 \times 10^{-5}$	0.097	$2.73 \times 10^{-34}$	$2.65 \times 10^{-32}$
rs2375980	9	2682622	$1.53 \times 10^{-27}$	$8.92 \times 10^{-9}$	0.022	$1.10 \times 10^{-34}$	$5.61 \times 10^{-34}$
rs10122587	9	2681951	$3.89 \times 10^{-24}$	NA	0.026	$3.89 \times 10^{-24}$	$6.74 \times 10^{-24}$
rs10967492	9	2671175	$1.86 \times 10^{-21}$	NA	0.11	$1.86 \times 10^{-21}$	$2.36 \times 10^{-20}$
rs10967470	9	2665698	$2.19 \times 10^{-21}$	NA	0.044	$2.19 \times 10^{-21}$	$4.96 \times 10^{-21}$
Model C							
rs6921438	6	44033585	$3.73 \times 10^{-507}$	NA	$3.54 \times 10^{-32}$	$3.73 \times 10^{-507}$	$1.22 \times 10^{-521}$
rs4513773	6	44033504	$4.54 \times 10^{-484}$	$1.13 \times 10^{-143}$	NA	$1.93 \times 10^{-625}$	$3.75 \times 10^{-589}$
rs9472159	6	44027673	$5.87 \times 10^{-454}$	$6.67 \times 10^{-113}$	$3.49 \times 10^{-30}$	$3.65 \times 10^{-563}$	$7.09 \times 10^{-556}$
rs9369434	6	44026385	$4.64 \times 10^{-445}$	$3.27 \times 10^{-65}$	$1.76 \times 10^{-26}$	$8.50 \times 10^{-495}$	$1.18 \times 10^{-504}$
rs1776717	6	44059314	$8.01 \times 10^{-20}$	$5.20 \times 10^{-4}$	$2.77 \times 10^{-5}$	$5.03 \times 10^{-22}$	$4.48 \times 10^{-26}$
rs1776721	6	43998961	$1.05 \times 10^{-19}$	$5.89 \times 10^{-9}$	0.025	$8.84 \times 10^{-27}$	$4.80 \times 10^{-27}$
rs1886979	6	44012879	$2.65 \times 10^{-19}$	$2.12 \times 10^{-6}$	$2.84 \times 10^{-3}$	$3.12 \times 10^{-24}$	$6.44 \times 10^{-26}$
rs9472155	6	44005705	$5.96 \times 10^{-19}$	$1.33 \times 10^{-9}$	0.010	$1.42 \times 10^{-26}$	$2.46 \times 10^{-27}$
rs844294	6	44008685	$1.63 \times 10^{-14}$	$1.95 \times 10^{-5}$	0.041	$1.71 \times 10^{-18}$	$5.41 \times 10^{-19}$
rs4416670	6	44058431	$1.16 \times 10^{-12}$	0.11	$1.49 \times 10^{-4}$	$1.38 \times 10^{-12}$	$1.48 \times 10^{-15}$
rs910611	6	44058829	$3.37 \times 10^{-10}$	$7.04 \times 10^{-6}$	0.076	$1.39 \times 10^{-14}$	$1.07 \times 10^{-14}$
rs6993770	8	106650704	$2.11 \times 10^{-16}$	$6.87 \times 10^{-8}$	$2.67 \times 10^{-3}$	$3.12 \times 10^{-22}$	$2.95 \times 10^{-24}$
rs16873402	8	106658423	$1.26 \times 10^{-14}$	$1.75 \times 10^{-8}$	0.043	$9.95 \times 10^{-21}$	$2.63 \times 10^{-21}$
rs16873365	8	106627411	$7.36 \times 10^{-12}$	$2.02 \times 10^{-6}$	0.26	$5.26 \times 10^{-16}$	$6.72 \times 10^{-16}$
rs7013321	8	106662734	$3.41 \times 10^{-12}$	NA	$2.21 \times 10^{-3}$	$3.41 \times 10^{-12}$	$2.90 \times 10^{-14}$
rs6993696	8	106650460	$6.23 \times 10^{-12}$	$2.09 \times 10^{-4}$	$2.57 \times 10^{-3}$	$6.00 \times 10^{-15}$	$6.22 \times 10^{-17}$
rs16873291	8	106597206	$4.25 \times 10^{-11}$	$9.77 \times 10^{-7}$	0.031	$1.00 \times 10^{-15}$	$1.04 \times 10^{-16}$
rs1349319	8	106625810	$2.33 \times 10^{-8}$	$1.61 \times 10^{-3}$	$7.71 \times 10^{-3}$	$1.51 \times 10^{-10}$	$4.18 \times 10^{-12}$
rs10738760	9	2681186	$1.91 \times 10^{-34}$	$5.53 \times 10^{-8}$	$9.24 \times 10^{-3}$	$2.94 \times 10^{-40}$	$7.37 \times 10^{-41}$
rs6475920	9	2663933	$3.43 \times 10^{-32}$	$9.54 \times 10^{-8}$	$6.55 \times 10^{-3}$	$2.33 \times 10^{-38}$	$8.21 \times 10^{-39}$
rs4741756	9	2658187	$5.22 \times 10^{-31}$	$2.27 \times 10^{-4}$	0.049	$2.71 \times 10^{-33}$	$1.28 \times 10^{-32}$
rs2375980	9	2682622	$1.15 \times 10^{-27}$	$8.63 \times 10^{-8}$	0.021	$1.01 \times 10^{-33}$	$7.71 \times 10^{-34}$
rs10122587	9	2681951	$4.10 \times 10^{-24}$	NA	0.027	$4.11 \times 10^{-24}$	$2.79 \times 10^{-24}$
rs10967492	9	2671175	$2.39 \times 10^{-21}$	NA	0.19	$2.39 \times 10^{-21}$	$3.15 \times 10^{-20}$
rs10967470	9	2665698	$2.66 \times 10^{-21}$	NA	0.096	$2.66 \times 10^{-21}$	$9.16 \times 10^{-21}$
Model D							
rs6921438	6	44033585	$1.53 \times 10^{-508}$	NA	$1.40 \times 10^{-40}$	$1.53 \times 10^{-508}$	$1.51 \times 10^{-529}$
rs4513773	6	44033504	$2.35 \times 10^{-485}$	$6.36 \times 10^{-136}$	NA	$4.72 \times 10^{-619}$	$1.67 \times 10^{-585}$
rs9472159	6	44027673	$1.61 \times 10^{-454}$	$4.22 \times 10^{-108}$	$1.52 \times 10^{-36}$	$8.63 \times 10^{-559}$	$3.15 \times 10^{-557}$
rs9369434	6	44026385	$6.46 \times 10^{-445}$	$7.63 \times 10^{-63}$	$2.70 \times 10^{-29}$	$3.63 \times 10^{-492}$	$3.43 \times 10^{-501}$
rs1776717	6	44059314	$2.43 \times 10^{-19}$	$2.96 \times 10^{-4}$	$7.08 \times 10^{-6}$	$6.53 \times 10^{-22}$	$1.76 \times 10^{-26}$
rs1776721	6	43998961	$7.12 \times 10^{-20}$	$4.46 \times 10^{-8}$	0.013	$3.12 \times 10^{-26}$	$1.14 \times 10^{-26}$
rs1886979	6	44012879	$1.54 \times 10^{-19}$	$2.15 \times 10^{-6}$	$7.09 \times 10^{-3}$	$1.85 \times 10^{-24}$	$2.03 \times 10^{-25}$
rs9472155	6	44005705	$1.37 \times 10^{-19}$	$1.37 \times 10^{-9}$	$4.11 \times 10^{-9}$	$7.78 \times 10^{-27}$	$1.49 \times 10^{-27}$
rs844294	6	44008685	$2.77 \times 10^{-15}$	$1.48 \times 10^{-5}$	0.048	$2.23 \times 10^{-19}$	$1.65 \times 10^{-19}$
rs4416670	6	44058431	$1.95 \times 10^{-12}$	0.088	$2.05 \times 10^{-4}$	$1.55 \times 10^{-12}$	$1.74 \times 10^{-15}$
rs910611	6	44058829	$3.19 \times 10^{-10}$	$3.45 \times 10^{-6}$	0.11	$7.40 \times 10^{-15}$	$1.70 \times 10^{-14}$
rs6993770	8	106650704	$5.19 \times 10^{-16}$	$5.30 \times 10^{-8}$	0.016	$7.22 \times 10^{-22}$	$9.86 \times 10^{-23}$
rs16873402	8	106658423	$3.72 \times 10^{-14}$	$1.34 \times 10^{-8}$	0.15	$2.91 \times 10^{-20}$	$1.10 \times 10^{-19}$
rs16873365	8	106627411	$2.38 \times 10^{-11}$	$3.87 \times 10^{-6}$	0.36	$2.99 \times 10^{-15}$	$1.14 \times 10^{-14}$
rs7013321	8	106662734	$8.07 \times 10^{-12}$	NA	0.013	$8.07 \times 10^{-12}$	$4.55 \times 10^{-13}$
rs6993696	8	106650460	$1.36 \times 10^{-11}$	$2.41 \times 10^{-4}$	0.040	$1.52 \times 10^{-14}$	$3.72 \times 10^{-15}$
rs16873291	8	106597206	$9.39 \times 10^{-11}$	$1.37 \times 10^{-6}$	0.071	$3.23 \times 10^{-15}$	$1.30 \times 10^{-15}$
rs1349319	8	106625810	$3.87 \times 10^{-8}$	$2.46 \times 10^{-3}$	0.057	$3.66 \times 10^{-10}$	$7.71 \times 10^{-11}$
rs10738760	9	2681186	$1.36 \times 10^{-35}$	$1.06 \times 10^{-8}$	0.046	$3.32 \times 10^{-42}$	$1.35 \times 10^{-40}$
rs6475920	9	2663933	$9.18 \times 10^{-33}$	$2.67 \times 10^{-8}$	0.018	$1.68 \times 10^{-39}$	$1.36 \times 10^{-38}$
rs4741756	9	2658187	$9.04 \times 10^{-32}$	$1.28 \times 10^{-4}$	0.071	$2.35 \times 10^{-34}$	$9.51 \times 10^{-33}$
rs2375980	9	2682622	$3.07 \times 10^{-28}$	$3.55 \times 10^{-8}$	0.015	$1.02 \times 10^{-34}$	$1.70 \times 10^{-34}$
rs10122587	9	2681951	$5.73 \times 10^{-25}$	NA	0.020	$5.73 \times 10^{-25}$	$6.91 \times 10^{-25}$

TABLE 4-continued

SNPID	Chr	Position	p (FHS)	p (PIVUS)	p (SFS)	Meta-p (FHS + PIVUS)*	Meta-p (all)†
rs10967492	9	2671175	$3.72 \times 10^{-22}$	NA	0.091	$3.72 \times 10^{-22}$	$3.50 \times 10^{-21}$
rs10967470	9	2665698	$5.48 \times 10^{-22}$	NA	0.045	$5.48 \times 10^{-22}$	$1.30 \times 10^{-21}$
Model E							
rs6921438	6	44033585	$6.58 \times 10^{-506}$	NA	$2.91 \times 10^{-39}$	$6.58 \times 10^{-506}$	$7.66 \times 10^{-524}$
rs4513773	6	44033504	$6.46 \times 10^{-482}$	$3.04 \times 10^{-138}$	NA	$6.76 \times 10^{-618}$	$1.66 \times 10^{-583}$
rs9472159	6	44027673	$9.84 \times 10^{-452}$	$4.86 \times 10^{-110}$	$4.30 \times 10^{-35}$	$4.42 \times 10^{-558}$	$1.30 \times 10^{-552}$
rs9369434	6	44026385	$2.44 \times 10^{-442}$	$3.05 \times 10^{-65}$	$5.33 \times 10^{-28}$	$1.10 \times 10^{-492}$	$6.10 \times 10^{-498}$
rs1776717	6	44059314	$9.92 \times 10^{-20}$	$2.53 \times 10^{-4}$	$1.00 \times 10^{-5}$	$2.40 \times 10^{-22}$	$8.47 \times 10^{-27}$
rs1776721	6	43998961	$5.41 \times 10^{-20}$	$2.57 \times 10^{-8}$	0.020	$1.47 \times 10^{-26}$	$1.30 \times 10^{-26}$
rs1886979	6	44012879	$2.55 \times 10^{-19}$	$1.66 \times 10^{-6}$	0.013	$2.41 \times 10^{-24}$	$7.07 \times 10^{-25}$
rs9472155	6	44005705	$1.74 \times 10^{-19}$	$3.04 \times 10^{-9}$	0.015	$7.84 \times 10^{-27}$	$4.93 \times 10^{-27}$
rs844294	6	44008685	$8.15 \times 10^{-15}$	$1.39 \times 10^{-5}$	0.086	$6.33 \times 10^{-19}$	$1.20 \times 10^{-18}$
rs4416670	6	44058431	$1.86 \times 10^{-12}$	0.11	$2.89 \times 10^{-4}$	$2.16 \times 10^{-12}$	$3.14 \times 10^{-15}$
rs910611	6	44058829	$2.35 \times 10^{-10}$	$1.99 \times 10^{-6}$	0.11	$3.34 \times 10^{-15}$	$8.62 \times 10^{-15}$
rs6993770	8	106650704	$1.34 \times 10^{-16}$	$3.63 \times 10^{-8}$	0.018	$1.27 \times 10^{-22}$	$2.52 \times 10^{-23}$
rs16873402	8	106658423	$1.24 \times 10^{-14}$	$8.58 \times 10^{-9}$	0.16	$6.38 \times 10^{-21}$	$3.39 \times 10^{-20}$
rs16873365	8	106627411	$8.10 \times 10^{-12}$	$4.01 \times 10^{-6}$	0.37	$9.32 \times 10^{-16}$	$5.17 \times 10^{-15}$
rs7013321	8	106662734	$3.64 \times 10^{-12}$	NA	0.014	$3.64 \times 10^{-12}$	$2.48 \times 10^{-13}$
rs6993696	8	106650460	$5.82 \times 10^{-12}$	$1.73 \times 10^{-4}$	0.047	$4.78 \times 10^{-15}$	$1.67 \times 10^{-15}$
rs16873291	8	106597206	$3.14 \times 10^{-11}$	$7.92 \times 10^{-7}$	0.066	$6.56 \times 10^{-16}$	$2.99 \times 10^{-16}$
rs1349319	8	106625810	$3.53 \times 10^{-8}$	$1.84 \times 10^{-3}$	0.046	$2.60 \times 10^{-10}$	$4.55 \times 10^{-11}$
rs10738760	9	2681186	$6.77 \times 10^{-35}$	$3.90 \times 10^{-9}$	0.034	$4.65 \times 10^{-42}$	$1.61 \times 10^{-40}$
rs6475920	9	2663933	$1.85 \times 10^{-32}$	$9.61 \times 10^{-9}$	0.022	$1.20 \times 10^{-39}$	$1.94 \times 10^{-38}$
rs4741756	9	2658187	$1.32 \times 10^{-31}$	$6.02 \times 10^{-5}$	0.092	$1.26 \times 10^{-34}$	$1.22 \times 10^{-32}$
rs2375980	9	2682622	$7.94 \times 10^{-28}$	$1.45 \times 10^{-8}$	0.022	$9.69 \times 10^{-35}$	$4.67 \times 10^{-34}$
rs10122587	9	2681951	$1.47 \times 10^{-24}$	NA	0.024	$1.47 \times 10^{-24}$	$2.56 \times 10^{-24}$
rs10967492	9	2671175	$6.75 \times 10^{-22}$	NA	0.10	$6.76 \times 10^{-22}$	$9.22 \times 10^{-21}$
rs10967470	9	2665698	$9.41 \times 10^{-22}$	NA	0.045	$9.41 \times 10^{-22}$	$2.39 \times 10^{-21}$

\*inverse variance meta-analysis;

†effective sample size weighted meta-analysis

## SEQUENCE LISTING

&lt;160&gt; NUMBER OF SEQ ID NOS: 9

&lt;210&gt; SEQ ID NO 1

&lt;211&gt; LENGTH: 623

&lt;212&gt; TYPE: DNA

&lt;213&gt; ORGANISM: Homo sapiens

&lt;220&gt; FEATURE:

&lt;221&gt; NAME/KEY: misc\_feature

&lt;222&gt; LOCATION: (323)..(323)

&lt;223&gt; OTHER INFORMATION: "n" is A or G

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atgagcagtt catctctcca gtaaattgtg tatcacagta aagaaagatc tcttgctggt 120

ctcacatate tttcattgta tttagtgc aa tgctgtaaac tttgaataac accatgggat 180

ctatacgaag tgccactagt gatgctggaa gtgctcccaa gaagcagagg aaagtcatta 240

cattcaagaa aaacttgaat tgcttgat atactgtaga ctgaggtctg cagctgtggt 300

taccaccat ttcaagataa acnaatccac tgtaaggacc accgtgaaaa aaagaaaagg 360

aaatttgtga agccatcact gcagctatgc cagtaggcac aaaaccttgc actttttgta 420

aaatgtcttt ttatcagctt gtatggtgag tgcaggattg ctataagaaa agtataccta 480

atattcaaga agtgaagtaa ttatatgaca agttaagca aaaggaaggt aaagactcta 540

aagctggaga atttaatgcc agcaaaggat ggtttaataa ttttaaaaag aggtttggct 600

tgaaaaatat taagataaca gaa 623

&lt;210&gt; SEQ ID NO 2

&lt;211&gt; LENGTH: 461

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<223> OTHER INFORMATION: "n" is C or T

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ggaaccagct tctaggtaa ctctcagaaa tcccacagtg ttggagtcac aagacctctg   180
agatacagcc ctccaagttt tctatggctg caaaacaac nattccaaa catagtgctt   240
taaaacaata atggcttaat ttctcacaat tctggtggtg gtcttgctg ttctgcaagt   300
ctaacctggg attagccac ttaatcagct gcattcagct ggaaggtcca gggtgacctc   360
aatggcaact ctgaagcctc cgtgccatca accggcttcc gtgtgcctcc tcttagtgcc   420
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<210> SEQ ID NO 3
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<212> TYPE: DNA
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<222> LOCATION: (235)..(235)
<223> OTHER INFORMATION: "n" is A or T

<400> SEQUENCE: 3
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ccctgcagac catatgctta ttatctatct tttatcttct taccctccc acttagaaca   180
atgtctagct tatactaaga gctcaatgaa taacattgaa tgaatcagca cattnatttt   240
ttcctttcac ttttctccat atcaggaaca gctgcacacc cctccttatt caagacctg   300
catccttctc gaggtcttac atccatgtct gtttcgtctg tgatcttget tcatctgect   360
aactcagcag agcaattacc acaggaaatg ctatcttcta cctgttttat ttgtttatag   420
acttgcaact ttatt                                           435

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<210> SEQ ID NO 4
<211> LENGTH: 401
<212> TYPE: DNA
<213> ORGANISM: Homo sapiens
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (201)..(201)
<223> OTHER INFORMATION: "n" is A or G

<400> SEQUENCE: 4
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gttcacccca tgacagggac ctgtagtagt ttctggagag ggcacaaagc agatggcagc   120
taatatccaa cgagagtcca catggaaaat gcaattttgt tctgtgagat gcagcacctc   180
ctgatggaag gaagtgggga naaatgagca ttttgaagac gcactttcca cttaccttgg   240
cacctgaaaa tcaactaggg ctcatctttt ccaaatacct ctaatcaacg gcagcaaggg   300
agaaggggta actttgggca taatgaagat gacaaaagaa tttactgac aatgactatg   360
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 <222> LOCATION: (251)..(251)  
 <223> OTHER INFORMATION: "n" is C or T

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ttctccttct tggaaactcta taatatcagg ataatgtcag tggagcagtt aatcctgggt    180
atctagaaat ggaatgggtg acccaacctt gatgttgccc tttacagcca catacctctg    240
cctggccttag ntataaagta ggaagtacca gtgtgggggt actgtgggct gaatgtctcc    300
attacctttg ggggtagaat cagctctggg agctctgttc ctgtttcctt ttggattcag    360
tatgatcttt tetgcctccc tttttcttca cctggaatga aagtgggtct agtgaagggc    420
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<210> SEQ ID NO 6  
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 <221> NAME/KEY: misc\_feature  
 <222> LOCATION: (251)..(251)  
 <223> OTHER INFORMATION: "n" is C or T

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tctataaatg gtttattttg ctcaagcttc agctatcttt tattagtctt ctttatagtg    180
gtatgttatt tttatcatct ttacagtcac atgaaagggt agtggaaata tcatttcctt    240
tatttcataa ntattctaac agttttcctc tgctgaatct agtagcaagt aaatgactat    300
taaaatgtat ttctttcttt aatgttttgt acatacagcc atagaagtct tgaaggaaaa    360
cttgactcag tatttattta gcatgttcca taagtcagga actcttctaa aatgtgggat    420
acaaaaatct gaatgcctcc cacacagaat tgcttcatgt aagagtattt aaatagaact    480
gaattctgtc catagccttt a                                         501

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<210> SEQ ID NO 7  
 <211> LENGTH: 501  
 <212> TYPE: DNA  
 <213> ORGANISM: Homo sapiens  
 <220> FEATURE:  
 <221> NAME/KEY: misc\_feature  
 <222> LOCATION: (251)..(251)  
 <223> OTHER INFORMATION: "n" is C or T

<400> SEQUENCE: 7

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aataaaaatac agatagtaat aattatggtt tacagaagta aaaatggcaa aggattatga    120
tgccttcag ggttgacggc tgtggttctt tgctgtctcc aggctctgcc ctactttggg    180
ctttagactt attcttagat tagttgtctc catggactcc gtgcagacat tggggagtag    240

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gggagctctt ntctctagcc aattttaaag aaaatatgaa cattaactct gattgctctg 300
gcttgaattg catgtccact tcttgaacca gtcattgtgc aagaaagaaa aaacaacttc 360
tttttttttt tttttttttt tttgagatgg agttttgctc tcgttgccca ggctgcagtg 420
cagtggcgty atcttggtcc actgcaactt ctgccttcgg ggtctccggg tccgagcaat 480
tctcttgccct cagcctccag a 501

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<212> TYPE: DNA
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<222> LOCATION: (501)..(501)
<223> OTHER INFORMATION: "n" is C or G

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gcatgaattc gcatttaaaa taaaagcagt ttggggctag gtgtggtggc tcatgcctgt 180
aatccagca ctttaggagg ctgaggaggg caaatcactt gaggtcagga gtttgaggcc 240
agcctggcca acatggtgaa accccatgtc tactaaaaat acaaaaatta gctgggagtg 300
atgagtcaca cttgtaatcc cagctacttg ggaggctgag gcaggagaat cgcttgatcc 360
tgggaggcag aggttgctgt gagctgagat tgcaccactg cactgcagcc tgagtgatag 420
agtgagactc catctcaaaa ataaataaac gaaattaat cacattaag cagtttgagc 480
tataaggctc taaaagtttt ntgcctcaaa actttggtga tgccgtcttt cccagtggcg 540
cttgtcttgt cttttggct gacctatctt cttttctctt tttactgtgg ccactctcta 600
agattccttg tttctagggt ccttcatttc tcatagcttt ggggaattca agccttgaa 660
gtgtcacctc aggattgggt tgccctgaat gcctcccaac ccctcctct ctctcagtc 720
ctttcctaaa ctcatctgcc ttgaatgcaa caaccagaat tttcttactt tcaacctttt 780
actcaatagt ttccaattat tttctctctc tcaagcttaa gccttctcaa attggatctg 840
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aataattggg gcaacc 916

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<210> SEQ ID NO 9
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<212> TYPE: DNA
<213> ORGANISM: Homo sapiens
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<221> NAME/KEY: misc_feature
<222> LOCATION: (301)..(301)
<223> OTHER INFORMATION: "n" is A or G

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tgggggctga gggcagagag tcccaggggc aggaatgggg acttcatcca tctctaagtt 180
tccaggtctg tgtcaggcaa tctggtctg tctgactct ccagagactg ataaaggtcc 240
gaggtgggty agagatgtcc acagagtctt tgctactct actgccaaga gttggtttct 300
rttttcctc tcttgatcc tggcttgccc ttatgacttg ctttgactga aaaaaatgca 360

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atgatgctgt gccagtccca ggc tcaaccc tagagag gcc tgactgcctt cctccctgt	420
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gagagactct ggaggatcag gcaactaagag gaggcgcacg gaagccggtt gatagcacgg	540
aggcttcaga gttgccattg aggccacct ggaccttcca gctgaatgca gctgattaag	600
t	601

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I claim:

1. A method for administering a VEGF-based therapy to a subject, the method comprising administering a VEGF-based therapy selected from bevacizumab, ranibizumab, lapatinib, sunitinib, sorafenib, axitinib, pazopanib, and thiazolidinedione to a subject known to have an allelic variant selected from the group consisting of:

- i. rs6921438, wherein a guanine residue is present at base 323 of SEQ ID No.1 at one or both alleles,
- ii. rs4416670, wherein a thymine residue is present at base 221 of SEQ ID No.2 at one or both alleles,
- iii. rs6993770, wherein a thymine residue is absent at base 235 of SEQ ID No.3 at one or both alleles, and
- iv. rs10738760, wherein a guanine residue is present at 201 of SEQ ID No.4 at one or both alleles.

2. A method for administering a VEGF-based therapy to a subject, the method comprising: screening a nucleic acid sample obtained from the subject to provide output information which identifies the presence or absence of the allelic variant rs6921438, wherein a guanine residue is detected at base 323 of SEQ ID No.1 at one or both alleles; and administering a VEGF-based therapy to the subject, wherein the VEGF-based therapy is selected from bevacizumab, ranibizumab, lapatinib, sunitinib, sorafenib, axitinib, pazopanib, and thiazolidinedione.

3. A method for administering a VEGF-based therapy to a subject, the method comprising: screening a nucleic acid sample obtained from the subject to provide output information which identifies the presence or absence of the allelic variant rs4416670, wherein a thymine residue is detected at base 221 of SEQ ID No.2 at one or both alleles; and administering a VEGF-based therapy to the subject, wherein the VEGF-based therapy is selected from bevacizumab, ranibizumab, lapatinib, sunitinib, sorafenib, axitinib, pazopanib, and thiazolidinedione.

4. A method for administering a VEGF-based therapy to a subject, the method comprising: screening a nucleic acid sample obtained from the subject to provide output information which identifies the presence or absence of the allelic variant rs6993770, wherein a thymine residue is not detected at base 235 of SEQ ID No.3 at one or both alleles; and administering a VEGF-based therapy to the subject, wherein the VEGF-based therapy is selected from bevacizumab, ranibizumab, lapatinib, sunitinib, sorafenib, axitinib, pazopanib, and thiazolidinedione.

5. A method for administering a VEGF-based therapy to a subject, the method comprising: screening a nucleic acid sample obtained from the subject to provide output information which identifies the presence or absence of the allelic variant rs10738760, wherein a guanine residue is detected at 201 of SEQ ID No.4 at one or both alleles; and administering a VEGF-based therapy to the subject, wherein the VEGF-based therapy is selected from bevacizumab, ranibizumab, lapatinib, sunitinib, sorafenib, axitinib, pazopanib, and thiazolidinedione.

6. The method of claim 2, wherein said screening comprises carrying out an in vitro assay with an array that identifies the presence or absence of the allelic variant.

7. The method of claim 3, wherein said screening comprises carrying out an in vitro assay with an array that identifies the presence or absence of the allelic variant.

8. The method of claim 4, wherein said screening comprises carrying out an in vitro assay with an array that identifies the presence or absence of the allelic variant.

9. The method of claim 5, wherein said screening comprises carrying out an in vitro assay with an array that identifies the presence or absence of the allelic variant.

10. The method of claim 2, further comprising, prior to said screening, obtaining a biological sample from the subject and isolating nucleic acid from the biological sample, to obtain the nucleic acid sample.

11. The method of claim 3, further comprising, prior to said screening, obtaining a biological sample from the subject and isolating nucleic acid from the biological sample, to obtain the nucleic acid sample.

12. The method of claim 4, further comprising, prior to said screening, obtaining a biological sample from the subject and isolating nucleic acid from the biological sample, to obtain the nucleic acid sample.

13. The method of claim 5, further comprising, prior to said screening, obtaining a biological sample from the subject and isolating nucleic acid from the biological sample, to obtain the nucleic acid sample.

14. The method of claim 10, wherein said screening comprises polymerase chain reaction (PCR), reverse transcriptase PCR (RT-PCR), isothermic amplification, nucleic acid sequence based amplification (NASBA), 5' fluorescence nuclease assay, molecular beacon assay, or rolling-circle amplification.

15. The method of claim 11, wherein said screening comprises polymerase chain reaction (PCR), reverse transcriptase PCR (RT-PCR), isothermic amplification, nucleic acid sequence based amplification (NASBA), 5' fluorescence nuclease assay, molecular beacon assay, or rolling-circle amplification.

16. The method of claim 12, wherein said screening comprises polymerase chain reaction (PCR), reverse transcriptase PCR (RT-PCR), isothermic amplification, nucleic acid sequence based amplification (NASBA), 5' fluorescence nuclease assay, molecular beacon assay, or rolling-circle amplification.

17. The method of claim 13, wherein said screening comprises polymerase chain reaction (PCR), reverse transcriptase PCR (RT-PCR), isothermic amplification, nucleic acid sequence based amplification (NASBA), 5' fluorescence nuclease assay, molecular beacon assay, or rolling-circle amplification.

18. The method of claim 14, wherein the biological sample is a blood sample.

19. The method of claim 15, wherein the biological sample is a blood sample.

20. The method of claim 16, wherein the biological sample is a blood sample.

21. The method of claim 17, wherein the biological sample is a blood sample.

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