

# **Performance and usability testing of an automated tool for detection of peripheral artery disease using electronic health records**

Ghazouri, I<sup>†1</sup>, Amal, S<sup>†1</sup>, Ho, V<sup>†1</sup>, Safarnejad, L<sup>1</sup>, Cabot, J<sup>1</sup>, Brown-Johnson, CG<sup>2</sup>, Leeper, N<sup>1,3</sup>, Asch, S<sup>2</sup>, Shah, NH<sup>3</sup>, Ross, EG\*<sup>1,3</sup>

<sup>1</sup>Division of Vascular Surgery, Department of Surgery, Stanford University School of Medicine, Stanford, CA; <sup>2</sup>Primary Care and Population Health, Department of Medicine, Stanford, CA; <sup>3</sup>Center for Biomedical Informatics Research, Department of Medicine, Stanford University School of Medicine, Stanford, CA

## Supplemental materials

**Supplemental Table 1.** All codes used in definition of peripheral artery disease cohort.

PAD Identification Codes	ICD-9	ICD-10	ICD-9-CM	ICD-10-PCS	CPT	Definition
Cases (codes used to include)	440.2*, 440.3*, 440.8, 440.4, 443.9, 736.3*, 736.4*, 736.5, 736.6, 736.7*, 736.8*, 736.9, 735.*, 754.3*, 754.4*, 754.5*, 754.6*, 754.7*, 755.02, 755.13, 755.14, 755.3, 755.4, 755.6*, 755.8, 759.7, 759.89, 895.*, 896.*, 897.*, 820.*, 821.*, 822.*, 823.*, 824.*, 825.*, 826.*, 827.*, 828.*, 829.*, 835.*, 836.*, 837.*, 838.*, 904.*, 928.*, 929.*, 959.6, 959.7, 996.4*, 996.66, 996.67, 996.77, 996.78	I70.2*, I70.3*, I70.4*, I70.5*, I70.6*, I70.7*, I70.8, I70.92, I73.9, M21.05*, M21.06*, M21.07*, M21.15*, M21.16*, M21.17*, M21.7*, M21.869, M21.6X*, M21.85*, M21.86*, M21.95*, M21.96*, M20.1*, M20.2*, M20.3*, M20.*, M20.5*, M20.6*, Q65.***, Q68.1*, Q68.2*, Q68.3*, Q68.4*, Q68.5*, Q66.3*, Q66.4*, Q66.5*, Q66.6*, Q66.7*, Q66.8*, Q69.2*, Q70.2*, Q70.3*, Q72.***, Q74.8, Q74.9,	39.50, 39.90, 38.18, 84.1*	047C3*, 047D3*, 047H3*, 047J3*, 047K3*, 047L3*, 047M3*, 047N3*, 047P3*, 047Q3*, 047R3*, 047S3*, 047T3*, 047U3*, 047V3*, 047W3*, 047Y3*, 04C00ZZ, 04C03ZZ, 04CC0Z*, 04CC3Z*, 04CC4Z*, 04CD*, 04CH*, 04CJ*, 04CK*, 04CK*, 04CL*, 04CM*, 04CN*, 04CP*, 04CQ*, 04CR*, 04CS*, 04CT*, 04CU*, 04CV*, 04CY*, 04100J7, 04100J8, 04100JF, 04100JG, 04100JH, 04100JJ, 04100JK, 041C0JD, 041C0JH, 041D0JF, 041D0JJ, 041H0JH, 041H0KJ, 041H4JH, 041J0JJ, 041J4JJ, 041K0J*, 041K0Z*, 041L09*, 041L0J*, 041L0K*, 041L0Z*, 041M*, 041N*, 041S0JQ, 041U0AP, 0Y6*	37205, 37206, 37207, 37208, 37236, 37237, 37184, 37185, 37186, 35302, 35303, 35304, 35305, 35306, 35331, 35351, 35355, 35361, 35363, 35371, 35372, 35381, 35452, 35454, 35456, 35459, 35470, 35472, 35473, 35474, 35483, 35492, 35493, 35495, 35521, 35533, 35537, 35538, 35539, 35540, 35556, 35558, 35563, 35565, 35566, 35571, 35583, 35585, 35587, 35621, 35623, 35637, 35638, 35646, 35647, 35654, 35656, 35661, 35663, 35665, 35666, 35671, 35700, 35876, 35879, 35881, 35883, 35884, 37184, 37185, 37186, 37205, 37206, 37207, 37208, 0236T, 0237T, 0238T, 37225, 37224, 37227, 37226, 37222, 37223, 37220, 37221, 37229, 37228, 37231, 37230, 37233, 37232,	Defined as at least 2 mentions of a concept code (ICD-9/10, CPT, Observation) in a visit or note

		Q89.7, E78.71, E78.72, Q87.2, Q87.3, Q87.5, Q87.81, Q87.82, Q87.89, Q89.8, S72.**, S82.**, S92.**, T14.8*, M24.35*, M24.36*, M24.37*, S83.**, S93.**, S75.**, S79.**, S99.**, S77.**, S89.**, T84.**			37235, 37234, 35548,  27590, 27591 ,27592, 27598, 27888, 27889, 28800, 28805	
Controls (codes used to exclude)	440.2*, 440.3*, 440.8, 440.4, 443.9	I70.2*, I70.3*, I70.4*, I70.5*, I70.6*, I70.7*, I70.8, I70.92, I73.9	39.50, 39.90, 38.18, 84.1*	047C3*, 047D3*, 047H3*, 047J3*, 047K3*, 047L3*, 047M3*, 047N3*, 047P3*, 047Q3*, 047R3*, 047S3*, 047T3*, 047U3*, 047V3*, 047W3*, 047Y3*, 04C00ZZ, 04C03ZZ, 04CC0Z*, 04CC3Z*, 04CC4Z*, 04CD*, 04CH*, 04CJ*, 04CK*, 04CK*, 04CL*, 04CM*, 04CN*, 04CP*, 04CQ*, 04CR*, 04CS*, 04CT*, 04CU*, 04CV*, 04CY*, 04100J7, 04100J8, 04100JF, 04100JG, 04100JH, 04100JJ, 04100JK, 041C0JD, 041C0JH, 041D0JF, 041D0JJ, 041H0JH,	37205, 37206, 37207, 37208, 37236, 37237, 37184, 37185, 37186, 35302, 35303, 35304, 35305, 35306, 35331, 35351, 35355, 35361, 35363, 35371, 35372, 35381, 35452, 35454, 35456, 35459, 35470, 35472, 35473, 35474, 35483, 35492, 35493, 35495, 35521, 35533, 35537, 35538, 35539, 35540, 35556, 35558, 35563, 35565, 35566, 35571, 35583, 35585, 35587, 35621, 35623, 35637, 35638, 35646,	

				041H0KJ, 041H4JH, 041J0JJ, 041J4JJ, 041K0J*, 041K0Z*, 041L09*, 041L0J*, 041L0K*, 041L0Z*, 041M*, 041N*, 041S0JQ, 041U0AP, 0Y6*	35647, 35654, 35656, 35661, 35663, 35665, 35666, 35671, 35700, 35876, 35879, 35881, 35883, 35884, 37184, 37185, 37186, 37205, 37206, 37207, 37208, 0236T, 0237T, 0238T, 37225, 37224, 37227, 37226, 37222, 37223, 37220, 37221, 37229, 37228, 37231, 37230, 37233, 37232, 37235, 37234, 35548, 27590, 27591 ,27592, 27598, 27888, 27889, 28800, 28805	
--	--	--	--	---	---	--

ICD-9/ICD-10 – International Classification of Diseases, 9<sup>th</sup> Version/10<sup>th</sup> Version. ICD-9-CM International Classification of Diseases, 9<sup>th</sup> Version – Clinical Modification. ICD-10-PCS - International Classification of Diseases, 10<sup>th</sup> Version – Procedure Coding System.

**Supplemental Table 2. Codes used to define co-morbidities used in traditional risk factor modeling.**

Disease	ICD-9	ICD-10	ICD-9-CM	ICD-10-PCS	CPT	Definition
Cerebrovascular disease	434, 434.01, 434.1, 434.9, 434.11, 434.91, 437, 437.1, 435, 435.1, 435.2, 435.3, 435.8, 435.9, 433, 433.01, 433.1, 433.11, 433.2, 433.21, 433.21, 433.3, 433.8, 433.31, 433.81, 433.9, 433.91	I66.01, I66.02, I66.03, I66.09, I66.11, I66.12, I66.13, I66.19, I66.21, I66.22, I66.23, I66.29, I66.3, I66.8, I63.30, I63.311, I63.312,	38.12, 0.61, 39.28, 0.63	03CL***, 03CH***, 03CJ***, 03CK***, 03CM***, 03CN***, 03CP***, 03CQ***, 03CG***, 037H***, 037J***, 037K***, 037L***, 037M***, 037N***, 037H***,	35301, 37215, 37216, 37195, 61645	Defined as at least 2 mentions of a concept code (ICD-9/10, CPT, Observation) in a visit or note

		I63.313, I63.319, I63.321, I63.322, I63.323, I63.329, I63.331, I63.332, I63.333, I63.339, I63.341, I63.342, I63.343, I63.349, I63.39, I63.6, I66.9, I63.40, I63.411, I63.412, I63.413, I63.419, I63.421, I63.422, I63.423, I63.429, I63.431, I63.432, I63.433, I63.439, I63.441, I63.442, I63.443, I63.449, I63.49, I63.50, I63.511, I63.512, I63.513, I63.519, I63.521, I63.522, I63.523, I63.529, I63.531, I63.532, I63.533, I63.539, I63.541, I63.542, I63.543, I63.549, I63.59, I63.8, I63.9, I67.2, I67.82, G45.0,		037J***, 037K***, 037L***, 037M***, 037N***		
--	--	--	--	---	--	--

		G45.8, G45.1, G45.2, G45.9, I65.1, I63.22, I63.02, I63.22, I65.29, I65.21, I65.22, I65.23, I63.031, I63.032, I63.033, I63.039, I63.131, I63.132, I63.133, I63.139, I63.239, I65.09, I65.01, I65.02, I65.03, I63.219, I63.211, I63.212, I63.213, I63.011, I63.012, I63.013, I63.019, I63.111, I63.112, I63.113, I63.119, I65.8, I63.59, I63.09, I63.19, I63.29, I65.9, I63.20, I63.00, I63.10				
Coronary artery disease	413, 413.1, 413.9, 411.1, 410, 410.01, 410.02, 410.1, 410.11, 410.12, 410.2, 410.21, 410.22, 410.4, 410.41, 410.42,	I20.8, I20.0, I21.01, I21.02, I21.09, I21.19, I21.11, I21.21, I21.29,	36.01, 36.02, 36.03, 36.04, 36.05, 36.06, 36.07, 36.09, 0.66,	Z98.61, Z95.5, 0270***, 0271***, 0272***, 0273***, 02C0***, 02C1***,	92920, 92921, 92924, 92925, 92928, 92929, 92933, 92934,	Defined as at least 2 mentions of a concept code (ICD9/10, CPT, Observation)

	410.3, 410.31, 410.32, 410.5, 410.51, 410.52, 410.6, 410.61, 410.62, 410.8, 410.81, 410.82, 410.7, 410.71, 410.72, 410.9, 410.91, 410.92, 412, 429.71, 429.79, 414, 414.01, 414.02, 414.03, 414.04, 414.05, 414.06, 414.07, 414.2, 414.3, 414.4, 414.8, 414.9	I21.4, I21.3, I21.3, I22.**, I25.2, I23.1, I23.2, I23.0, I23.3, I23.4, I23.5, I23.6, I23.7, I23.8, I24.1, I25.10, I25.810, I25.811, I25.812, I25.110, I25.111, I25.118, I25.119, I25.700, I25.701, I25.708, I25.709, I25.710, I25.711, I25.718, I25.719, I25.720, I25.721, I25.728, I25.729, I25.730, I25.731, I25.738, I25.739, I25.750, I25.751, I25.758, I25.759, I25.760, I25.761, I25.768, I25.769, I25.790, I25.791, I25.798, I25.799, I25.82, I25.83, I25.84, I25.5, I25.89, I25.9	V45.82, 36.1, 36.11, 36.12, 36.13, 36.14, 36.15, 36.16, 36.17, 36.18, 36.19, 36.2, V45.81	02C2***, 02C3***, 02703ZZ, 02704ZZ, 02713ZZ, 02714ZZ, 02723ZZ, 02724ZZ, 02733ZZ, 02734ZZ, 3E07017, 3E070PZ, 3E07317, 3E073PZ, Z95.1, 0210***, 0211***, 0212***, 0213***	92937, 92938, 92941, 92943, 92944, 92980, 92981, 92982, 92984, 92995, 92996, 92973, 92974, 33510, 33511, 33512, 33513, 33514, 33516, 33517, 33518, 33519, 33521, 33522, 33523, 33533, 33534, 33535, 33536	
--	---	---	---	---	---	--

Heart failure	398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 425.**, 428.**	I09.81, I11.0, I13.0, I13.2, I25.5, I42.*, I50.**, Z95.811	37.66, V43.21	02HA0QZ, 02HA4QZ, 02HA3QZ	33979, 33982, 33983, 93750	Defined as at least 2 mentions of a concept code (ICD9/10, CPT, Observation)
Hypertension	401.**, 402.**, 403.**, 404.**, 405.**	I10.**, I11.**, I12.**, I13.**, I15.**				Defined using at least 2 mentions of a concept code (ICD9/10, Observation)
Diabetes	250.**	E10.**, E12.**, E13.**, E14.**				Defined using at least 1 mention of a concept code (ICD9/10, Observation) AND on at least 1 glycemic medication OR Hemaglobin A1c (hgbA1c) > 6.4
Hyperlipidemia	272.0*, 272.1*, 272.2*, 272.4*	E78.0*, E78.1*, E78.2*, E78.4*, E78.5*				Defined using at least 1 mention of a concept code (ICD9/10, Observation) AND on at least 1 lipid medication OR cholesterol >= 200 OR LDL >= 100 OR triglycerides >= 150
Obesity	278.00, 278.01	E66.0, E66.01, E66.09, E66.9				Defined using at least 2 mentions of a concept code (ICD9/10, Observation) OR a body mass index measurement >= 30
Current smoker			305.1	F17.210, F12.213, F17.218, F17.219,		At least 2 codes during their care

				O99.330, O99.331, O99.332, O99.333, O99.334, O99.335, T65.221, T65.222, T65.223, T65.224, Z71.6, Z72.0		
--	--	--	--	--	--	--

ICD-9/ICD-10 – International Classification of Diseases, 9<sup>th</sup> Version/10<sup>th</sup> Version. ICD-9-CM International Classification of Diseases, 9<sup>th</sup> Version – Clinical Modification. ICD-10-PCS - International Classification of Diseases, 10<sup>th</sup> Version – Procedure Coding System.

**Supplemental Table 3.** Logistic regression model performance for outer 5-folds.

	<b>AUC</b>	<b>Specificity</b>	<b>Sensitivity</b>	<b>Standard Dev.</b>	<b>95% CI</b>
<b>Fold 1</b>	0.807	0.736	0.73	0.0108	0.786-0.818
<b>Fold 2</b>	0.798	0.678	0.774	0.0105	0.778-0.822
<b>Fold 3</b>	0.819	0.742	0.751	0.0103	0.798-0.839
<b>Fold 4</b>	0.826	0.712	0.792	0.0099	0.807-0.846
<b>Fold 5</b>	0.802	0.782	0.680	0.0103	0.782-0.822
<b>Average</b>	0.810	0.730	0.746		

AUC – area under the curve

**Supplemental Table 4.** Nomogram model performance for outer 5-folds.

	<b>AUC</b>	<b>Specificity</b>	<b>Sensitivity</b>	<b>Standard Dev.</b>	<b>95% CI</b>
<b>Fold 1</b>	0.641	0.708	0.558	0.0270	0.588-0.694
<b>Fold 2</b>	0.616	0.551	0.603	0.0279	0.567-0.671
<b>Fold 3</b>	0.633	0.538	0.644	0.0280	0.579-0.688
<b>Fold 4</b>	0.658	0.598	0.680	0.0276	0.604-0.712
<b>Fold 5</b>	0.660	0.688	0.610	0.0272	0.607-0.713
<b>Average</b>	0.642	0.617	0.619		

Nomogram scores are calculated based on patient demographic features in accordance to Duval et al (2012). AUC – area under the curve.

**Supplemental Table 5.** Machine learning model performance for outer 5-folds using random forest architecture.

	<b>AUC</b>	<b>Specificity</b>	<b>Sensitivity</b>	<b>Standard Dev.</b>	<b>95% CI</b>
--	------------	--------------------	--------------------	----------------------	---------------

<b>Fold 1</b>	0.908	0.797	0.845	0.0061	0.896-0.919
<b>Fold 2</b>	0.904	0.802	0.819	0.0061	0.892-0.916
<b>Fold 3</b>	0.911	0.832	0.817	0.0063	0.898-0.923
<b>Fold 4</b>	0.909	0.815	0.836	0.0062	0.897-0.921
<b>Fold 5</b>	0.914	0.792	0.852	0.0056	0.902-0.925
<b>Average</b>	0.909	0.808	0.834		

AUC – area under the curve; CI – Confidence interval.

**Supplemental Table 6.** Deep learning model performance for outer 5-folds.

	<b>AUC</b>	<b>Specificity</b>	<b>Sensitivity</b>	<b>Standard Dev.</b>	<b>95% CI</b>
<b>Fold 1</b>	0.968	0.895	0.944	0.0018	0.959-0.976
<b>Fold 2</b>	0.963	0.860	0.970	0.0016	0.954-0.972
<b>Fold 3</b>	0.956	0.869	0.922	0.0023	0.946-0.966
<b>Fold 4</b>	0.956	0.885	0.944	0.0022	0.945-0.967
<b>Fold 5</b>	0.974	0.868	0.970	0.0016	0.967-0.981
<b>Average</b>	0.963	0.875	0.950		

AUC – area under the curve; CI – Confidence interval.