Supplemental Online Content

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This supplemental material has been provided by the authors to give readers additional information about their work.

eMethods.

Natural language processing for Gleason score.
We developed a rule-based natural language processing (NLP) system to extract Gleason scores from clinical documents, including pathological reports from prostate specimens and reporting of pathological results in other cancer-related clinical notes, including clinical notes from Oncology, Radiation Oncology, Urology, and chemotherapy infusion providers. The NLP system extracted the highest reported Gleason score from each document. The system was evaluated with two validation studies. First, performance was assessed on 200 randomly selected pathology documents involving a prostate specimen. The system showed excellent performance, with an accuracy of 0.995, recall of 1.0, and precision of 0.988.

Tables. Results of Gleason NLP algorithm validation on 200 randomly selected Pathology documents involving a prostate specimen.

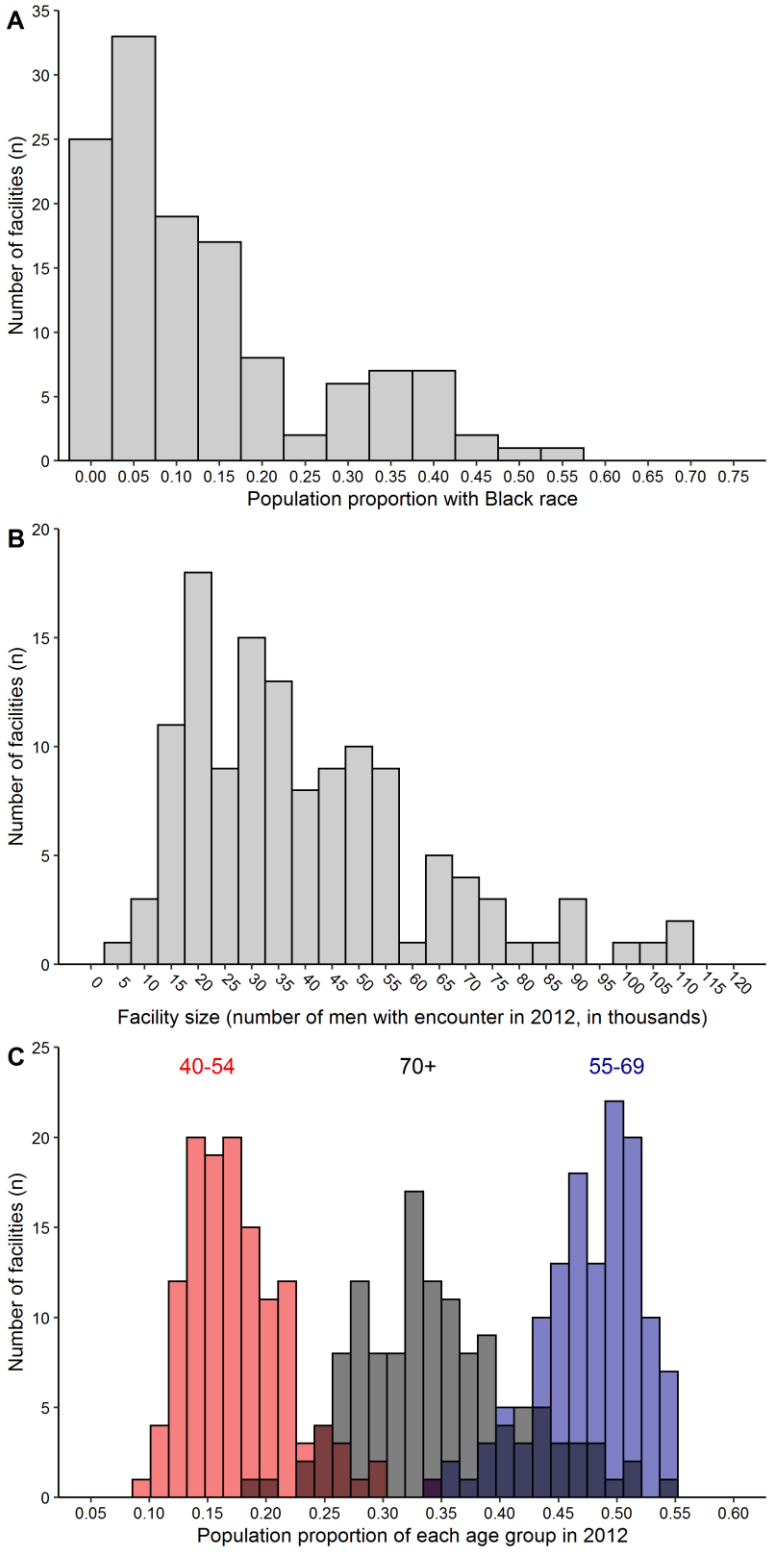
	Classified		
Actual		Negative	Positive
	Negative	120	1
	Positive	0	79

Metric	**Value**
True Positive:	79
False Positive:	1
True Negative:	120
False Negative:	0
Precision:	0.988
Recall:	1.0
Accuracy:	0.995

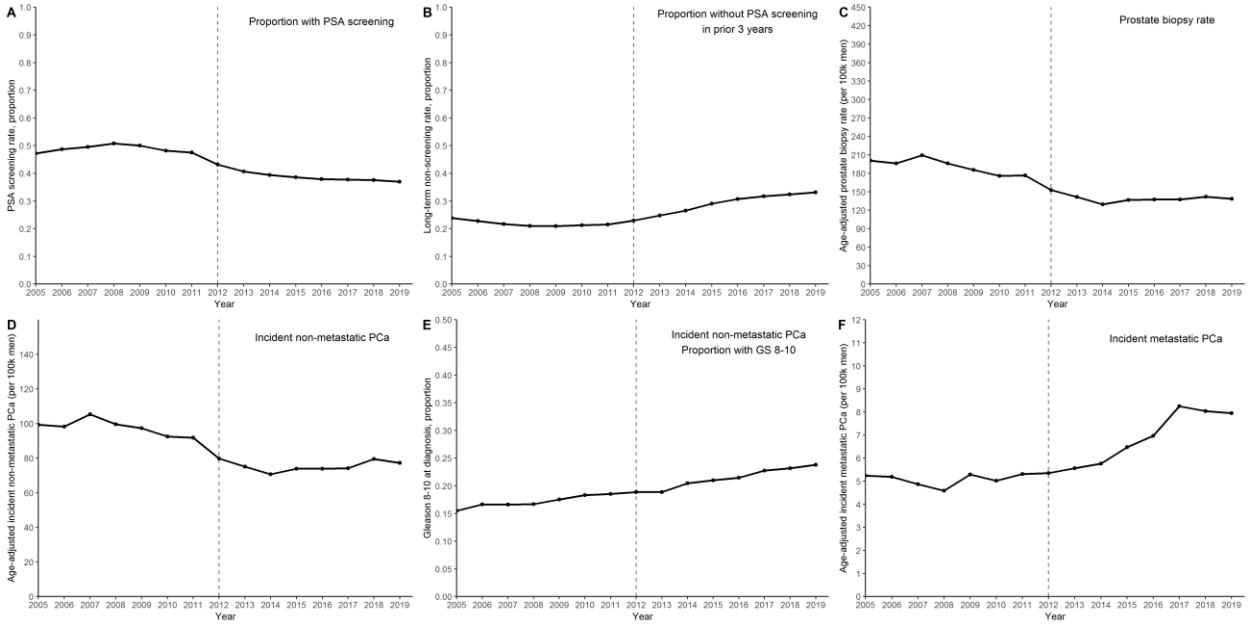
We next validated the performance of the NLP algorithm on cancer-related non-Pathology documents by manually reviewing 100 extracted Gleason scores derived from these documents. This system showed a precision of 97%.

Concordance of PSA laboratory data with CPT codes.
Total PSA tests were extracted from structured laboratory data in the Corporate Data Warehouse using a hand-curated list of laboratory test names reflecting total PSA measurements. We examined concordance of the structured PSA laboratory data with CPT codes for PSA testing (CPT 84152, 84153, G0103). Among all patients with a PSA result in laboratory data (8.17 M), 97.5% also had a concordant CPT code for PSA testing. Similar results were found among 618,493 patients with PSA results in laboratory data before the date of prostate cancer diagnosis (96.9% with concordant CPT code).

eFigure 1. **Characteristics of 128 Veterans Healthcare Administration facilities included in the primary analysis.** Histograms of (A) population proportion of patients with Black race in each facility in 2012, (B) facility size measured by the number of men with any encounter in each facility in 2012, (C) population proportion of each age group in 2012.



eFigure 2. Pooled PSA screening, prostate biopsy, and prostate cancer incidence rates. (**A**) Pooled PSA screening rates, (**B**) long-term non-screening rates (representing the proportion of patients without a PSA screening test in the prior 3 years), (**C**) prostate biopsy rate, (**D**) non-metastatic prostate cancer incidence rates, (**E**) proportion of non-metastatic prostate cancer with Gleason 8-10, and (**F**) metastatic prostate cancer incidence rates. All rates are pooled across 128 Veterans Healthcare Administration facilities. Vertical dotted line represents the year of USPSTF screening guideline publication in 2012. Shaded area represents 95% confidence interval. PSA: Prostate-specific antigen; PCa: prostate cancer; GS: Gleason score.



eTable 1. Screening and diagnosis rates by age group

Age group	Year	Men with VHA encounter (n)	Incident mPCa (n)	Screening PSA[a]	No screening PSA in prior 3 years[a]	Prostate biopsy rate[b]	Incident nmPCa with Gleason 8-10[a]	Incident nmPCa[b]	Incident mPCa[b]
40-54	2005	946,240	53	0.398	0.319	260.6	0.079	103.1	5.6
	2006	891,490	39	0.411	0.309	250.6	0.112	101.4	4.4
	2007	871,965	36	0.421	0.299	256.7	0.107	117.6	4.1
	2008	869,632	32	0.437	0.291	251.9	0.110	111.5	3.7
	2009	902,361	49	0.439	0.286	250.1	0.127	121.3	5.4
	2010	908,969	39	0.423	0.287	244.0	0.103	114.0	4.3
	2011	918,242	51	0.414	0.290	237.4	0.130	111.1	5.6
	2012	923,314	34	0.372	0.311	212.1	0.124	101.8	3.7
	2013	924,061	29	0.350	0.338	184.2	0.120	91.0	3.1
	2014	934,820	37	0.338	0.361	161.5	0.089	79.2	4.0
	2015	928,387	40	0.329	0.384	167.8	0.133	81.5	4.3
	2016	920,822	37	0.326	0.397	166.9	0.137	86.3	4.0
	2017	914,502	45	0.327	0.403	159.5	0.123	80.2	4.9
	2018	921,917	32	0.330	0.406	168.7	0.134	87.2	3.5
	2019	934,615	27	0.333	0.409	159.3	0.121	80.8	2.9
55-69	2005	1,835,360	303	0.578	0.138	960.0	0.119	422.9	16.5
	2006	1,916,159	315	0.594	0.126	940.0	0.129	427.1	16.4
	2007	1,985,117	319	0.602	0.116	1012.0	0.126	461.0	16.1
	2008	2,052,798	324	0.617	0.109	959.6	0.130	451.2	15.8
	2009	2,181,622	356	0.613	0.108	935.7	0.143	454.8	16.3
	2010	2,289,145	405	0.593	0.110	896.9	0.156	447.2	17.7
	2011	2,407,301	452	0.585	0.110	914.5	0.160	452.8	18.8
	2012	2,483,384	495	0.539	0.117	799.4	0.166	395.5	19.9
	2013	2,510,680	465	0.515	0.129	763.6	0.160	377.7	18.5
	2014	2,530,602	509	0.504	0.142	713.3	0.183	362.4	20.1
	2015	2,501,134	563	0.496	0.160	746.5	0.185	378.1	22.5
	2016	2,440,006	568	0.490	0.173	751.8	0.194	375.9	23.3
	2017	2,303,817	640	0.492	0.179	743.5	0.195	378.1	27.8
	2018	2,111,876	614	0.497	0.182	758.0	0.206	399.3	29.1
	2019	1,936,969	533	0.500	0.184	731.5	0.199	385.1	27.5
70+	2005	1,896,812	488	0.407	0.295	458.5	0.208	350.6	25.7
	2006	1,906,227	491	0.415	0.292	436.7	0.225	324.3	25.8
	2007	1,877,928	443	0.418	0.286	473.4	0.234	332.5	23.6
	2008	1,836,983	430	0.420	0.283	418.9	0.238	301.9	23.4
	2009	1,826,809	509	0.398	0.291	351.1	0.256	256.5	27.9
	2010	1,791,221	446	0.372	0.306	320.2	0.268	237.3	24.9
	2011	1,776,070	481	0.359	0.319	317.4	0.269	224.3	27.1
	2012	1,768,360	510	0.313	0.343	254.8	0.275	184.9	28.8
	2013	1,772,797	593	0.283	0.366	246.2	0.294	175.8	33.4
	2014	1,804,055	584	0.271	0.388	233.4	0.295	173.2	32.4
	2015	1,850,948	648	0.267	0.417	262.5	0.292	190.0	35.0
	2016	1,929,723	798	0.266	0.434	280.1	0.284	188.5	41.4
	2017	2,093,854	966	0.275	0.431	311.3	0.310	209.5	46.1
	2018	2,306,932	1,076	0.282	0.420	348.1	0.286	240.2	46.6
	2019	2,500,117	1,140	0.283	0.417	359.3	0.301	239.8	45.6

[a]Expressed as a proportion. [b]Expressed as an age-specific crude rate per 100,000 men.
VHA: Veterans Health Administration; mPCa: metastatic prostate cancer; PSA: Prostate specific antigen; nmPCA: non-metastatic prostate cancer.

eTable 2. Screening and diagnosis rates by race.

Race	Year	Men with VHA encounter (n)	Incident mPCa (n)	Screening PSA[a]	No screening PSA in prior 3 years[a]	Prostate biopsy rate[b]	Incident nmPCa with Gleason 8-10[a]	Incident nmPCa[b]	Incident mPCa[b]
Black	2005	581,810	228	0.480	0.200	379.4	0.151	244.4	16.2
	2006	593,254	214	0.504	0.183	383.4	0.153	226.5	15.2
	2007	613,081	198	0.515	0.170	402.0	0.159	238.7	13.6
	2008	637,147	203	0.534	0.161	369.1	0.161	223.1	12.7
	2009	678,243	242	0.531	0.156	354.0	0.167	216.4	15.1
	2010	707,615	197	0.517	0.155	313.4	0.169	188.7	12.9
	2011	739,812	266	0.508	0.156	319.0	0.173	192.4	13.6
	2012	768,069	272	0.465	0.168	293.2	0.173	172.3	13.4
	2013	791,551	261	0.444	0.185	270.3	0.167	160.8	12.6
	2014	814,079	288	0.434	0.202	243.5	0.183	145.5	13.0
	2015	829,360	360	0.429	0.223	246.9	0.201	146.7	16.2
	2016	842,062	372	0.424	0.235	261.2	0.203	151.8	16.7
	2017	853,654	434	0.426	0.240	261.9	0.196	152.8	17.8
	2018	865,272	435	0.428	0.243	261.8	0.207	157.2	17.0
	2019	875,598	442	0.431	0.245	262.2	0.207	154.4	16.6
White	2005	3,130,797	523	0.492	0.217	188.5	0.156	90.7	4.6
	2006	3,219,393	550	0.503	0.210	179.5	0.169	88.9	4.7
	2007	3,271,043	525	0.510	0.201	190.8	0.166	93.9	4.3
	2008	3,306,806	487	0.521	0.195	177.8	0.168	87.9	4.0
	2009	3,434,737	579	0.512	0.197	164.1	0.179	82.9	4.6
	2010	3,511,644	597	0.491	0.203	156.9	0.188	80.1	4.2
	2011	3,609,880	621	0.484	0.206	154.6	0.191	77.7	4.5
	2012	3,672,923	665	0.438	0.221	128.8	0.195	64.8	4.4
	2013	3,697,786	724	0.411	0.240	118.0	0.200	59.8	5.0
	2014	3,747,411	750	0.397	0.260	108.1	0.214	56.9	5.0
	2015	3,752,475	790	0.387	0.286	114.5	0.214	58.9	5.2
	2016	3,751,842	899	0.379	0.306	110.3	0.222	57.5	5.8
	2017	3,759,630	1,084	0.376	0.317	111.1	0.246	58.0	6.9
	2018	3,768,605	1,143	0.372	0.325	115.1	0.244	62.9	6.7
	2019	3,771,936	1,109	0.364	0.335	110.8	0.255	60.5	6.7
Other[c]	2005	245,640	44	0.507	0.210	298.4	0.142	135.2	5.7
	2006	254,355	30	0.516	0.198	265.7	0.147	119.1	4.1
	2007	262,637	36	0.520	0.191	280.4	0.159	122.8	5.1
	2008	272,948	47	0.531	0.185	241.2	0.156	108.1	5.3
	2009	286,218	54	0.520	0.185	212.0	0.157	101.9	6.2
	2010	291,987	61	0.497	0.193	192.0	0.175	94.2	6.5
	2011	300,709	65	0.488	0.200	199.2	0.172	93.8	6.4
	2012	309,375	62	0.440	0.218	163.2	0.187	81.4	6.2
	2013	318,529	66	0.414	0.243	151.0	0.176	72.5	6.0
	2014	331,259	70	0.399	0.267	135.2	0.198	65.8	6.3
	2015	339,603	74	0.393	0.291	141.7	0.217	73.5	6.9
	2016	348,035	98	0.388	0.307	134.6	0.197	66.6	8.2
	2017	357,730	97	0.384	0.315	132.7	0.201	62.4	8.0
	2018	369,673	103	0.386	0.321	138.7	0.232	69.6	7.9
	2019	382,127	116	0.380	0.328	133.6	0.232	68.2	9.9
Unknown	2005	720,165	49	0.365	0.371	79.5	0.181	23.3	1.9
	2006	646,874	51	0.378	0.369	77.8	0.240	23.1	2.1

Race	Year	Men with VHA encounter (n)	Incident mPCa (n)	Screening PSA[a]	No screening PSA in prior 3 years[a]	Prostate biopsy rate[b]	Incident nmPCa with Gleason 8-10[a]	Incident nmPCa[b]	Incident mPCa[b]
	2007	588,249	39	0.384	0.366	78.6	0.236	24.7	1.7
	2008	542,512	49	0.386	0.369	72.0	0.235	23.1	2.0
	2009	511,594	39	0.375	0.376	67.4	0.229	20.6	1.6
	2010	478,089	35	0.358	0.384	63.3	0.243	18.2	2.0
	2011	451,212	32	0.347	0.393	65.9	0.215	19.2	1.5
	2012	424,691	40	0.310	0.411	53.7	0.241	16.7	2.2
	2013	399,672	36	0.287	0.435	50.8	0.224	16.8	1.8
	2014	376,728	22	0.280	0.453	43.4	0.268	14.2	1.5
	2015	359,031	27	0.274	0.480	47.2	0.175	15.1	1.9
	2016	348,612	34	0.272	0.494	45.8	0.234	15.6	2.4
	2017	341,159	36	0.273	0.503	43.5	0.273	15.6	2.5
	2018	337,175	41	0.276	0.505	49.2	0.252	19.7	3.0
	2019	342,040	33	0.274	0.511	45.4	0.258	15.3	2.4

[a]Expressed as a proportion. [b]Expressed as a rate per 100,000 men, age-adjusted to the 2000 US standard population. [c]Hispanic and Asian.
VHA: Veterans Health Administration; mPCa: metastatic prostate cancer; PSA: Prostate specific antigen; nmPCA: non-metastatic prostate cancer.

eTable 3. Results of mixed effects negative binomial regressions for metastatic PCa rates among frequent Veterans Health Administration users.

	Model for PSA screening rate				Model for long-term non-screening rate		
Variable	**Incidence rate ratio[a]**	**95% CI**	**p-value**		**Incidence rate ratio[a]**	**95% CI**	**p-value**
PSA screening rate or long-term non-screening rate[c]	0.88	0.83-0.94	<0.001		1.13	1.02-1.24	0.017
Percent Black race[c]	1.16	1.08-1.26	<0.001		1.18	1.09-1.28	<0.001
Calendar year (spline)[d]	--	--	<0.001		--	--	<0.001
Percent age 70+[c]	1.15	1.01-1.30	0.041		1.13	0.99-1.29	0.07
Availability of novel PET tracers	1.07	0.97-1.18	0.2		1.06	0.96-1.17	0.3
Usage of MRI pelvis for prostate cancer workup[c,e]	0.98	0.94-1.03	0.5		0.99	0.94-1.03	0.5
Region: Pacific	(reference)	--	--		(reference)	--	--
Region: Continental	0.73	0.53-0.99	0.044		0.68	0.49-0.94	0.020
Region: Midwest	0.90	0.67-1.20	0.5		0.85	0.63-1.15	0.3
Region: North Atlantic	0.72	0.54-0.97	0.032		0.69	0.51-0.95	0.021
Region: Southeast	0.79	0.57-1.10	0.2		0.73	0.51-1.02	0.068

[a] Coefficients reflect the metastatic prostate cancer incidence rate ratio associated with a unit change in each predictor.
[b] Long-term non-screening rates represent the percentage of men aged 40+ without a prior history of prostate cancer who had not received a PSA test in the prior 3 years.
[c] Reported per 10% increase.
[d] P-value for spline term generated by the likelihood ratio test.
[e] Defined as the proportion of newly-diagnosed prostate cancer cases with MRI pelvis performed within +/- 3 months of the date of diagnosis.
Abbreviations: CI: Confidence interval; PSA: Prostate specific antigen; mPCa: metastatic prostate cancer; PET: positron emission tomography.