Online-Only Supplementary Material

Contents

Supplementary Table 1. Appropriateness of Diabetes Therapy Indicator (ADTI) specification codes. Diagnosis codes used to ascertain health conditions used to determine clinical complexity and measure exclusion criteria.

Health condition	ICD-9 codes	ICD-10 codes
Hypoglycemia	251.0, 251.1, 251.2, 270.3, 962.3 or 250.8x (and not 259.8, 272.7, 681.xx, 682.xx, 686.9x, 707.1-707.9, 709.3, 730.0-730.2, 731.8)	E08.641, E08.649, E09.641, E09.649, E10.641, E10.649, E11.641, E11.649, E13.641, E13.649, E15, E16.0, E16.1, E16.2, T383X1A, T383X1D, T383X1S, T383X2A, T383X2D, T383X2S, T383X3A, T383X3D, T383X3S, T383X4A, T383X4D, T383X4S, T383X5A, T383X5D, T383X5S
	ICD-9 codes from Ginde, et al(1); ICD-10 codes were adapted by study investigators based on clinical expertise	
Dementia	046.1x, 290.1x, 290.2x, 290.3, 290.4x, 291.2, 292.82, 294.1x, 294.2x, 331.0, 331.1x, 331.2, 331.6, 331.82, 331.89	A81.0x, F01.5x, F02.8x, F03.9x, F10.27, F10.97, F13.27, F13.97, F18.97, F19.17, F19.27, F19.97, G30.x, G31.0x, G31.1, G31.83, G31.85
	Adapted from cohort definition in NQF-endorsed quality measure "Antipsychotic Use in Persons with Dementia" and American Academy of Neurology's "Diagnosis (active) dementia group" value set (found in VSAC)	
End-stage renal disease	585.5, 585.6, 403.01, 403.11, 403.91, 404.02, 404.03, 404.12, 404.13, 404.92, 404.93, V45.11	N18.5, N18.6, I12.0, I13.11, I13.2
	Investigator developed algorithm based on clinical expertise and literature review	
Chronic kidney disease, stage 3-4	585.3, 585.4	N18.3, N18.4
	Investigator developed algorithm based on clinical expertise and literature review	
Myocardial infarction	410.xx, 412	I21.xx, I22.x, I25.2
	Adapted from AHRQ CCS category 100 (2)	
Heart failure	398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 428.xx	I09.81, I11.0, I13.0, I13.2, I50.xx
	Adapted from the cohort for the NQF-endorsed CMS "Hospital 30-day, all-cause, risk-standardized readmission rate (RSRR) following heart failure (HF) hospitalization" measure (ACO-37; NQF #0330)(3; 4)	
Cerebrovascular disease	430, 431, 432.x, 433.xx, 434.xx, 435.x, 436, 437.x, 438.xx, V12.54	G45.0, G45.1, G45.2, G45.8, G45.9, G46.x, I60.xx, I61.x (except I61.0), I62.xx, I63.xxx, I65.xx, I66.xx, I67.8x (except I67.83, I67.84), I67.9, I69.xxx, Z86.73
	Adapted from "Cerebrovascular disease, Stroke, TIA" value set from Quality Insights of Pennsylvania (QIP) from VSAC	
Chronic obstructive pulmonary disease	490, 491.xx, 492.x, 494.x, 496	J40, J41.x, J42, J43.x, J44.x, J47.x
	Definition taken from the chronic obstructive pulmonary disease and asthma chronic disease group in the NQF-endorsed CMS "All-Cause Unplanned Admissions for	

	Patients with Multiple Chronic Conditions" measure (ACO-38)(5)	
Metastatic cancer	196.xx, 197.xx, 198.xx	C77.xx, C78.xx, C79.xx
	Taken from AHRQ CCS categories 11-22; 24-43 (2)	
Non-metastatic cancer (except non-melanoma skin cancer)	14x.xx, 15x.xx, 160.x-165.x, 170.x-172.x, 174.x-176.x, 179-189.x, 19x.xx, 200.xx-208.xx (except 196.xx, 197.xx, 198.xx, 203.x1, 204.x1, 205.x1, 206.x1, 207.x1, 208.x1)	C00.x-C14.x, C15.x-C26.x, C3x.xx, C40.xx-C41.x, C43.x, C4A.xx, C45.x-C49.xx, C50.xxx, C51.x-C58, C60.x-C63.x, C64.x-C68.x, C69.xx-C72.x, C73-C76.x, C80.x, C7A.xx, C81.xx-C96.x (except C90.x1, C91.x1, C92.x1, C93.x1, C94.x1, C95.x1)
	Taken from AHRQ CCS categories 11-22; 24-43 (2)	
Cirrhosis	571.2, 571.5, 571.6	K70.3x, K74.3, K74.4, K74.5, K74.6x
	Taken from "Cirrhosis" value set from MITRE (found on VSAC)	
Proliferative retinopathy	361.xx, 362.02, 362.53, 369.xx, 379.23	H33.xxx, E11.359x, H35.359, H54.xx, H43.1x
	Adapted from Glasheen, et al(6) and the NQF-endorsed CMS "Risk-Standardized Acute Admission Rates for Patients with Diabetes" measure (ACO-36) (7)	
Blindness	360.41, 360.42, 368.30, 368.31, 369.xx, 377.75	H44.51, H44.52, H47.61, H53.30, H53.34, H54.xx
	Investigator developed algorithm based on clinical expertise and literature review	
Peripheral neuropathy	250.6x, 354.x, 355.x, 356.9, 357.2, 713.5	E10.40, E10.42, E11.40, E11.42, E13.42, G56.x, G57.x, G58.x, G60.9, M14.6x
	Adapted from Glasheen, et al(6) and the NQF-endorsed CMS "Risk-Standardized Acute Admission Rates for Patients with Diabetes" measure (ACO-36) (7)	
Lower extremity ulcers	707.0x-707.2x	L89.xx, L97.xx,
	Investigator developed algorithm based on clinical expertise and literature review	
Amputation	V49.7	Z89.4x-Z89.6x
	Investigator developed algorithm based on clinical expertise and literature review	
Arthritis	711.2x, 714.xx (except 714.81), 715.xx, 720.x, 725	M05.xxx, M06.xxx, M12.0xx, M35.2, M45.x, M46.1, M46.8x, M46.9x, M49.8x, M35.3
	Taken from AHRQ CCS categories 202-203, 205 (2)	
Urinary incontinence	625.6, 788.30, 788.31, 788.32, 788.33, 788.34, 788.38, 788.39, 788.91	N39.3, N39.41, N39.42, N39.46, N39.490, N39.492, N39.498, R32, R39.81
	Investigator developed algorithm based on clinical expertise and literature review	
Depression	311, 290.13, 290.21, 290.43, 296.2x, 296.3x, 296.82, 298.0, 301.12, 309.0, 309.1, 309.28	F01.51, F32.xx (except F32.81), F33.xx, F34.8x, F43.21, F43.23
	Adapted from "Depression" value set from Quality Insights of Pennsylvania (found on VSAC)	

Falls	E88x.x, E987.x	W00.xxxx, W01.xxxx, W03.xxxx, W04.xxxx, W05.xxxx, W06.xxxx, W07.xxxx, W08.xxxx, W09.xxxx, W10.xxxx, W11.xxxx, W12.xxxx, W13.xxxx, W14.xxxx, W15.xxxx, W16.xxxx, W17.xxxx, W18.xxxx, W19.xxxx, Y30.XXXA
	Investigator developed algorithm based on clinical expertise and literature review	

Abbreviations: ACO, Accountable Care Organization; CCS, Clinical Classification Software ; MI, myocardial infarction; VSAC, United States National Library of Medicine Value Set Authority Center

Codes used for exclusion

Pregnancy state (exclusion criterion)	ICD-9: 630.xx-679.xx, V22.x, V23.x ICD-10: O00-O9A, Z33.x, Z34.x
Hospice enrollment (exclusion criterion)	Discharge status: 50, 51 Place of service: 34 UB codes: 0115, 0125, 0135, 0145, 0155, 0235, 065x CPT codes: 99377, 99378 HCPC codes: G0182, G9473-G9479, G9475, G9687, G9688, G9690-G9694, G9700, G9702, G9707, G9709, G9710, G9713-G9715, G9718, G9720, G9723, G9725, G9740, G9741, G9758, G9760, G9761, G9768, G9802, G9805, G9809, G9819, G9857, G9860, G9861, Q5001-Q5008, Q5010, S9126, T2042-T2046

Severe hyperglycemia (outcome) codes

ICD-9 codes	**ICD-10 codes**
250.1x, 250.2x	E10.10, E10.11, E11.00, E11.01, E11.10, E11.11 E13.00, E13.01, E13.10, E13.11

Supplementary Table 2. Study population.

	High complexity (N=24,604)	Low complexity (N=181,675)	Total (N=206,279)
Age group, years	74.1 (9.8)	64.3 (11.9)	65.5 (12.1)
Mean (SD)			
18-44	171 (0.7%)	10981 (6.0%)	11152 (5.4%)
45-64	3995 (16.2%)	75376 (41.5%)	79371 (38.5%)
65-74	6469 (26.3%)	60617 (33.4%)	67086 (32.5%)
≥75	13969 (56.8%)	34701 (19.1%)	48670 (23.6%)
Sex			
Female	13874 (56.4%)	88500 (48.7%)	102374 (49.6%)
Male	10730 (43.6%)	93175 (51.3%)	103905 (50.4%)
Race/ethnicity			
White	14647 (59.5%)	106765 (58.8%)	121412 (58.9%)
Black	4568 (18.6%)	29375 (16.2%)	33943 (16.5%)
Hispanic	3776 (15.3%)	28971 (15.9%)	32747 (15.9%)
Asian	1066 (4.3%)	12207 (6.7%)	13273 (6.4%)
Unknown/missing	547 (2.2%)	4357 (2.4%)	4904 (2.4%)
U.S. region			
Midwest	4370 (17.8%)	30965 (17.0%)	35335 (17.1%)
Northeast	5709 (23.2%)	33893 (18.7%)	39602 (19.2%)
South	12910 (52.5%)	96879 (53.3%)	109789 (53.2%)
West	1615 (6.6%)	19938 (11.0%)	21553 (10.4%)
Annual household income			
<$40,000	11177 (45.4%)	50943 (28.0%)	62120 (30.1%)
$40,000-$49,999	2732 (11.1%)	17298 (9.5%)	20030 (9.7%)
$50,000-$59,999	2102 (8.5%)	16033 (8.8%)	18135 (8.8%)
$60,000-$74,999	2359 (9.6%)	20181 (11.1%)	22540 (10.9%)
$75,000-$99,999	2456 (10.0%)	25867 (14.2%)	28323 (13.7%)
≥$100,000	2583 (10.5%)	44740 (24.6%)	47323 (22.9%)
Unknown	1195 (4.9%)	6613 (3.6%)	7808 (3.8%)
Attributed provider			
Family medicine	10291 (41.8%)	87619 (48.2%)	97910 (47.5%)
Internal medicine	12055 (49.0%)	77734 (42.8%)	89789 (43.5%)
Endocrinology	713 (2.9%)	8876 (4.9%)	9589 (4.6%)
Unattributed	1545 (6.3%)	7446 (4.1%)	8991 (4.4%)
Health plan			
Commercial	1956 (7.9%)	79800 (43.9%)	81756 (39.6%)
Medicare Advantage	22648 (92.1%)	101875 (56.1%)	124523 (60.4%)

Supplementary Table 3. Comorbidity profile of clinically complex patients in the study population. One patient could meet several criteria for clinical complexity.

	Clinically Complex (N=24,604)
Severe hypoglycemia	1305 (5.3%)
Dementia	4231 (17.2%)
ESRD	2657 (10.8%)
Metastatic cancer	1220 (5.0%)
≥ 4 chronic conditions	18984 (77.2%)
Age ≥75 years	13969 (56.8%)
Myocardial infarction	3478 (14.1%)
Heart failure	9122 (37.1%)
Cerebrovascular disease	9142 (37.2%)
COPD	9213 (37.4%)
Stage 3-4 chronic kidney disease	8665 (35.2%)
Cancer	5850 (23.8%)
Arthritis	11326 (46.0%)
Urinary incontinence	3010 (12.2%)
Falls	3030 (12.3%)
Depression	6630 (26.9%)
Cirrhosis	619 (2.5%)
Retinopathy, blindness	1898 (7.7%)
Neuropathy, ulcers, amputation	13835 (56.2%)

Supplementary Table 4. Characteristics of patients designated as undertreated, appropriately treated, or overtreated by the Appropriate Diabetes Treatment Indicator (ADTI). All percentages are calculated across rows.

	Potentially Undertreated (N=43,532)	Appropriate (N=147,434)	Potentially Overtreated (N=15,313)	p-value
Primary provider				<0.001
Internal Medicine	17797 (19.8%)	65397 (72.8%)	6595 (7.3%)	
Family Medicine	21827 (22.3%)	69095 (70.6%)	6988 (7.1%)	
Endocrinology	1947 (20.3%)	6671 (69.6%)	971 (10.1%)	
Other	1961 (21.8%)	6271 (69.7%)	759 (8.4%)	
Health plan				<0.001
Commercial	22315 (27.3%)	54467 (66.6%)	4974 (6.1%)	
Medicare Advantage	21217 (17.0%)	92967 (74.7%)	10339 (8.3%)	
Clinical complexity				<0.001
Low	41007 (22.6%)	131118 (72.2%)	9550 (5.3%)	
High	2525 (10.3%)	16316 (66.3%)	5763 (23.4%)	
Age group				<0.001
18-44 years	3622 (32.5%)	6661 (59.7%)	869 (7.8%)	
45-64 years	21206 (26.7%)	53035 (66.8%)	5130 (6.5%)	
65-74 years	12237 (18.2%)	50176 (74.8%)	4673 (7.0%)	
≥75 years	6467 (13.3%)	37562 (77.2%)	4641 (9.5%)	
Gender				<0.001
Male	23440 (22.6%)	72795 (70.1%)	7670 (7.4%)	
Female	20092 (19.6%)	74639 (72.9%)	7643 (7.5%)	
Race				<0.001
White	23765 (19.6%)	88050 (72.5%)	9597 (7.9%)	
Black	8032 (23.7%)	23269 (68.6%)	2642 (7.8%)	
Hispanic	8263 (25.2%)	22410 (68.4%)	2074 (6.3%)	
Asian	2527 (19.0%)	10077 (75.9%)	669 (5.0%)	
Unknown	945 (19.3%)	3628 (74.0%)	331 (6.7%)	
Region				<0.001
Midwest	6938 (19.6%)	25337 (71.7%)	3060 (8.7%)	
Northeast	7639 (19.3%)	29194 (73.7%)	2769 (7.0%)	
South	23798 (21.7%)	77929 (71.0%)	8062 (7.3%)	
West	5157 (23.9%)	14974 (69.5%)	1422 (6.6%)	
Income				<0.001
<$40,000	12309 (19.8%)	44695 (71.9%)	5116 (8.2%)	
$40,000-$49,999	4304 (21.5%)	14224 (71.0%)	1502 (7.5%)	
$50,000-$59,999	4012 (22.1%)	12900 (71.1%)	1223 (6.7%)	
$60,000-$74,999	4950 (22.0%)	15986 (70.9%)	1604 (7.1%)	

$75,000-$99,999	6318 (22.3%)	20067 (70.9%)	1938 (6.8%)
≥$100,000	9854 (20.8%)	34186 (72.2%)	3283 (6.9%)
Unknown	1785 (22.9%)	5376 (68.9%)	647 (8.3%)

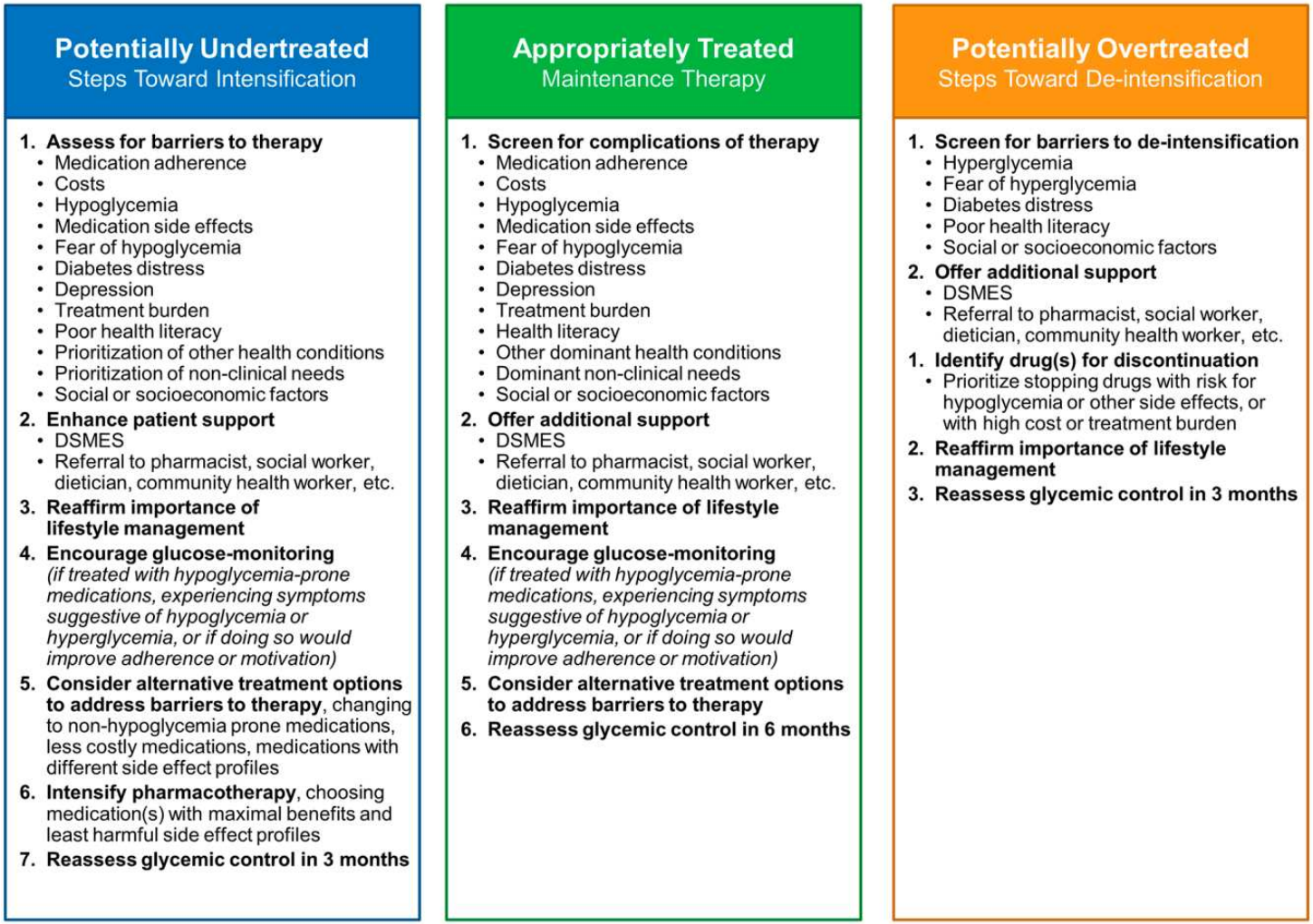
Supplementary Table 5. Comparison of the ADTI to existing dichotomous measures of glycemic control. Current quality measures of glycemic control apply a uniform dichotomous threshold of HbA_{1c} <8.0% to all adults ages 18-75. This table compares the proportion of patients deemed appropriately treated by the Appropriate Diabetes Treatment Indicator (ADTI) versus existing dichotomous measure for all patients, patients ≥18 to ≤75 years, and patients >75 years. Percent patients undertreated, appropriately treated, and overtreated are calculated across rows, by HbA_{1c} level.

	Number of patients	Potentially Undertreated	Appropriately Treated	Potentially Overtreated
Overall				
< 8%	159,855	11,495 (7.2%)	133,047 (83.2%)	15,313 (9.6%)
≥ 8%	46,424	32,037 (69.0%)	14,387 (31.0%)	--
≥18 to ≤75 years				
< 8%	123,406	9541 (7.7%)	102,657 (83.2%)	11,208 (9.1%)
≥ 8%	40,378	28,476 (70.5%)	11,902 (29.5%)	--
>75 years				
< 8%	36,449	1954 (5.4%)	30,390 (83.4%)	4105 (11.3%)
≥ 8%	6046	3561 (58.9%)	2485 (41.1%)	--

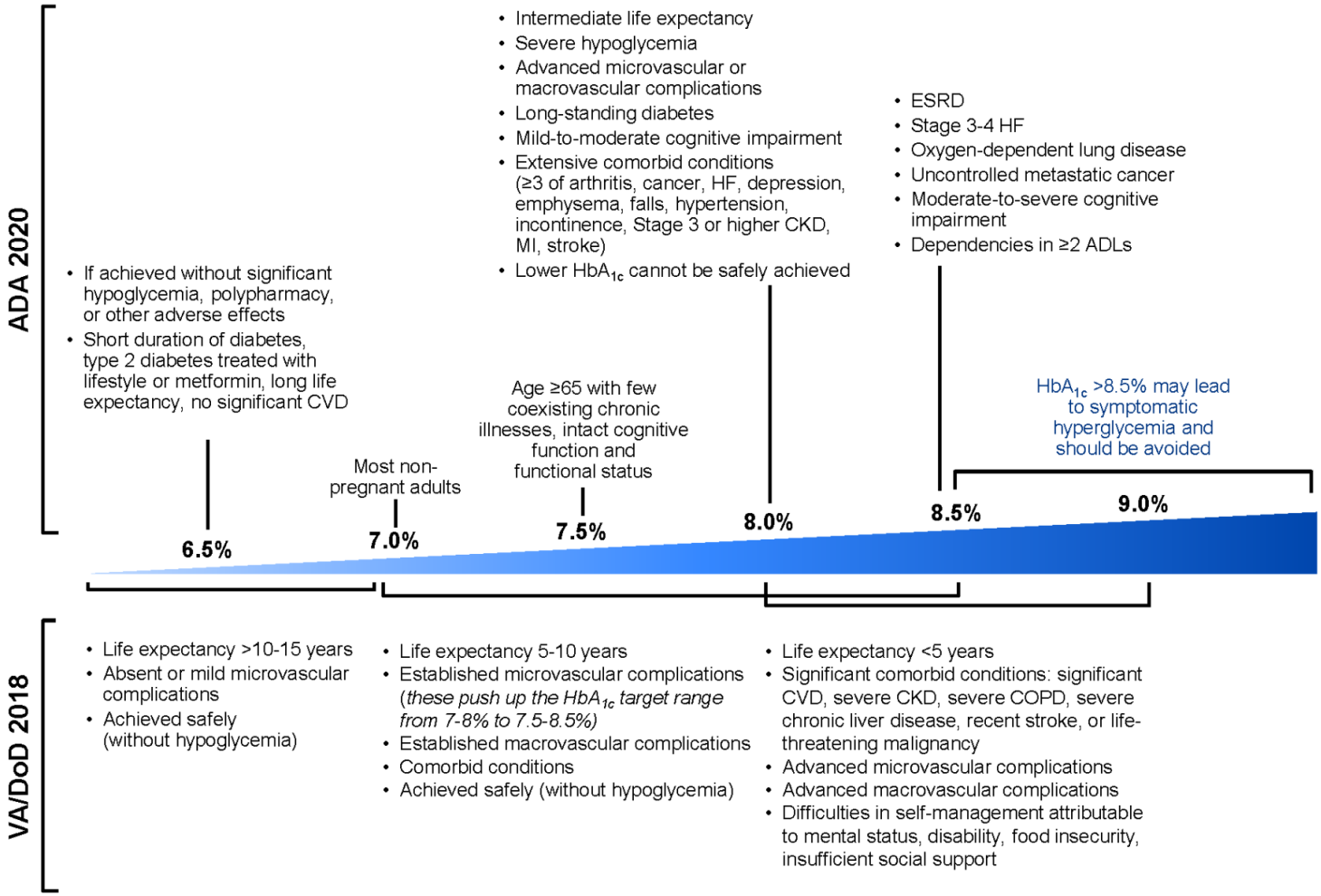
Supplementary Table 6. Provider-level variation in ADTI performance. The proportions of internal medicine, family medicine, and endocrinology specialists whose attributed patients are potentially undertreated, appropriately treated, and potentially overtreated. Data presented as median and interquartile range (Q1, Q3) and calculated only for clinicians with ≥25 attributed patients.

	Internal Medicine (N=270)	**Family Medicine (N=224)**	**Endocrinology (N=16)**	**P-value**
Appropriately treated	77.0% (71.0 - 84.0)	74.3% (67.9 - 80.6)	71.5% (67.8 - 82.7)	0.002
Potentially undertreated	15.4% (9.4 - 21.2)	18.5% (11.1 - 25.0)	13.6% (5.7 - 18.1)	0.001
Potentially overtreated	6.6% (3.1 - 10.3)	6.9% (3.7 - 10.3)	11.0% (7.1 - 16.1)	<0.001

Supplementary Figure 1. Provider action recommendations in response to ADTI results for individual patients.



Supplementary Figure 2. Glycemic targets as recommended by clinical practice guidelines. Summary of recommendations provided in the 2017 U.S. Department of Veterans Affairs/ Department of Defense (VA/DoD) and 2020 American Diabetes Association (ADA) clinical practice guidelines.



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