

**Development of a healthcare system COVID hotspotting score in California: an observational study with prospective validation**

Vincent X Liu, MD MSc  
Khanh K Thai, MS  
Jessica Galin, MPH  
Lawrence David Gerstley, PhD  
Laura C Myers, MD  
Stephen M Parodi, MD  
Yi-Fen Irene Chen, MD  
Nancy Goler, MD  
Gabriel J Escobar, MD  
Patricia Kipnis, PhD

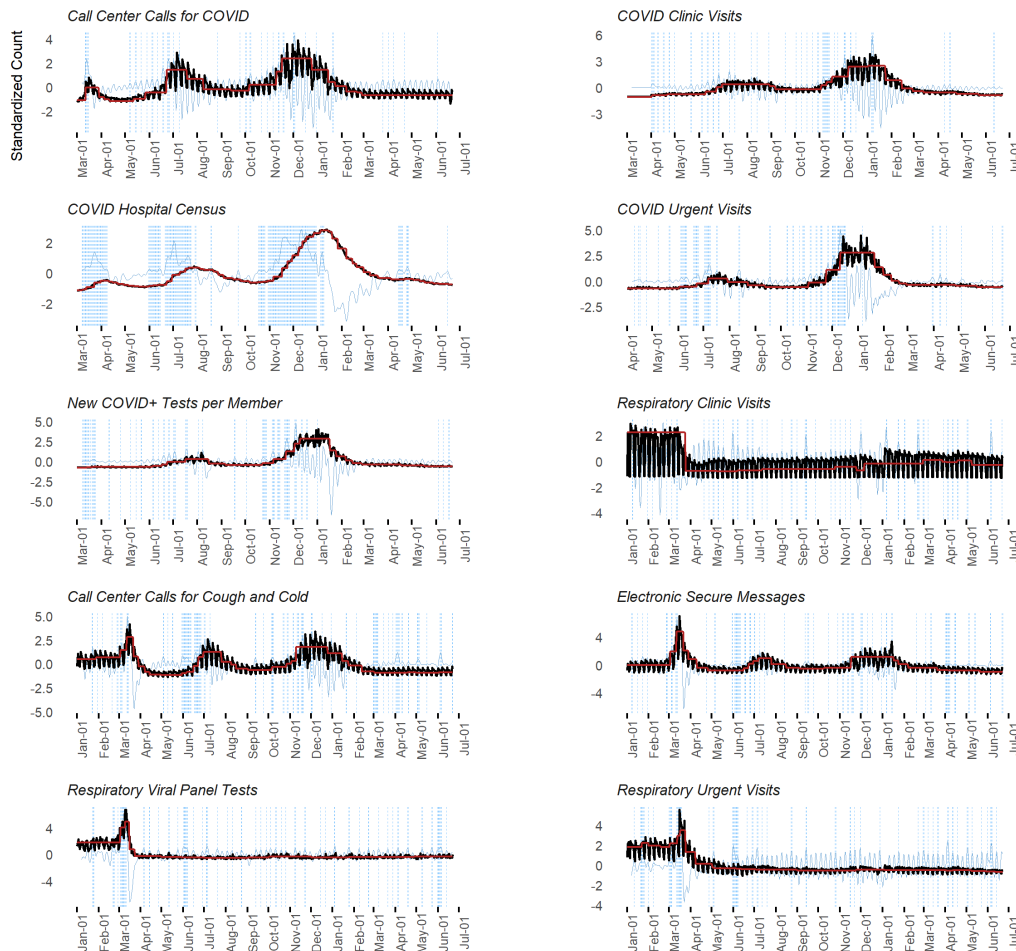
**Web appendix for interested readers**

**Appendix Table 1. Characteristics of KPNC Adult Population by 6 Main Sub-regional Areas.**

Characteristic	Location						
	KPNC Region	A	B	C	D	E	F
N	3,293,223	389,617	575,166	548,614	652,390	640,139	487,297
Age [Mean (SD)]	48 (18.0)	47 (17.8)	49 (18.2)	47 (17.6)	49 (18.4)	49 (18.2)	47 (17.6)
Male [N (%)]	1,564,615 (47.5%)	187,739 (48.2%)	269,400 (46.8%)	257,902 (47.0%)	300,273 (46.0%)	310,066 (48.4%)	239,235 (49.1%)
<b>Race [N (%)]</b>							
Asian	631,943 (19.2%)	42,513 (10.9%)	92,414 (16.1%)	141,987 (25.9%)	85,792 (13.2%)	132,078 (20.6%)	137,159 (28.1%)
Black	217,373 (6.6%)	22,818 (5.9%)	48,462 (8.4%)	67,134 (12.2%)	48,461 (7.4%)	19,053 (3.0%)	11,445 (2.3%)
Hispanic	669,053 (20.3%)	129,643 (33.3%)	101,769 (17.7%)	115,969 (21.1%)	97,577 (15.0%)	105,179 (16.4%)	118,916 (24.4%)
White	1,419,661 (43.1%)	151,582 (38.9%)	274,659 (47.8%)	160,421 (29.2%)	353,256 (54.1%)	315,167 (49.2%)	164,576 (33.8%)
Other	355,193 (10.8%)	43,061 (11.1%)	57,862 (10.1%)	63,103 (11.5%)	67,304 (10.3%)	68,662 (10.7%)	55,201 (11.3%)
COPS2* [Mean (SD)]	14.8 (17.2)	14.7 (17.1)	15.1 (17.8)	14.4 (16.6)	15.6 (18.7)	14.6 (16.7)	14.0 (16.0)

\* The COPS2 (COMorbidity Point Score, version 2), described in Escobar et al. (2013) is a score assigned every month to all adults with a Kaiser Permanente Northern California medical record number. Range is from 0 to 1010; higher scores indicate worse mortality risk. The univariate relationship between the COPS2 and 1-year mortality is as follows: 0-39, 0.3%; 40-64, 5.3%; 65+, 17.2%.

**Appendix Figure 1. Timeline of each of 10 leading indicators between January 1, 2020 and September 30, 2020 along with data indicative of statistical significance testing based on the Change Point algorithm and moving 7-day slope changes.** The dark line indicates the actual standardized count of each indicator and the red line indicates linear plateaus identified by the change point detection algorithm. Blue lines over time indicate the slope changes (ranging from positive when standardized counts are increasing and negative when counts are decreasing) with dotted blue vertical dashed lines indicative of periods when the slope change is positive and statistically significant.



**Appendix Table 2. Contribution of daily statistical significance test combinations to indicator scores.** Major indicators contributed double the weight of minor indicators.

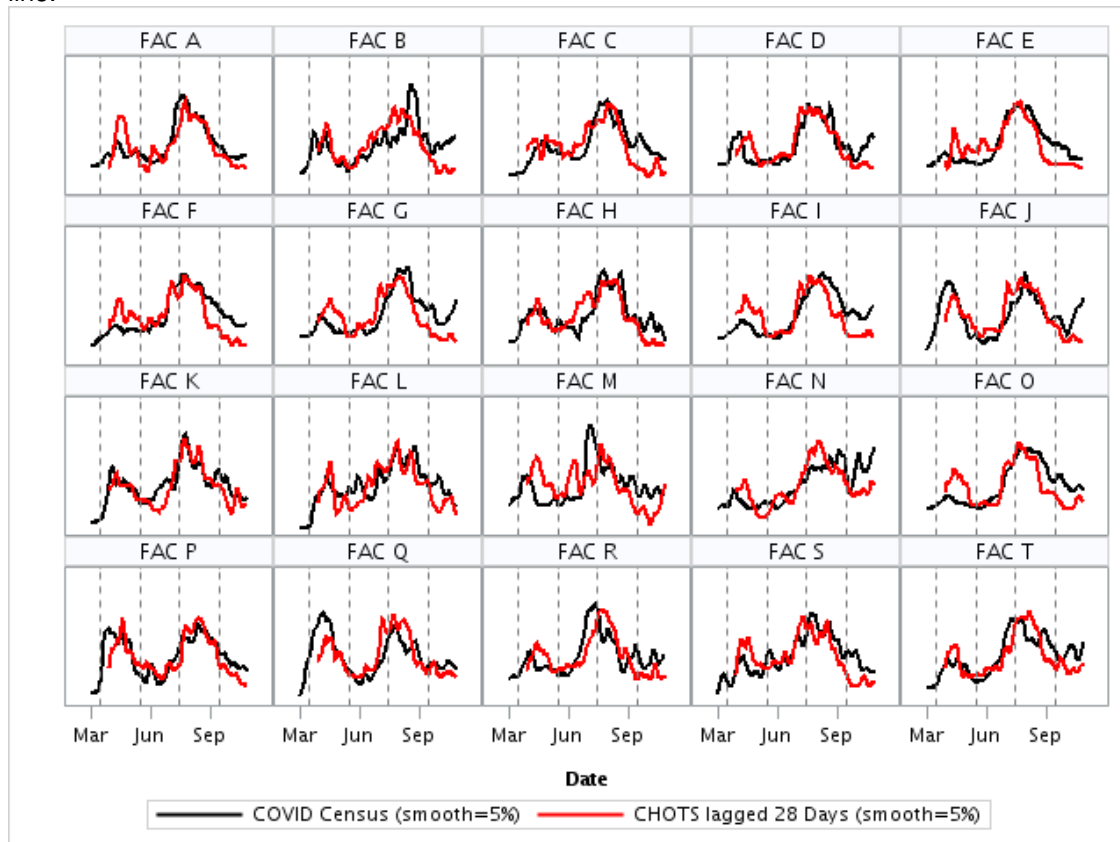
Is daily change statistically significant?			
Change point analysis		Slope change	Raw score value
Baseline	Last		
No	No	No	0.0
No	No	Yes	0.2
No	Yes	No	0.6
No	Yes	Yes	1.2
Yes	No	No	0.0
Yes	No	Yes	0.4
Yes	Yes	No	1.0
Yes	Yes	Yes	1.4/1.6*

\*Value of 1.6 is only for COVID-specific hospital census.

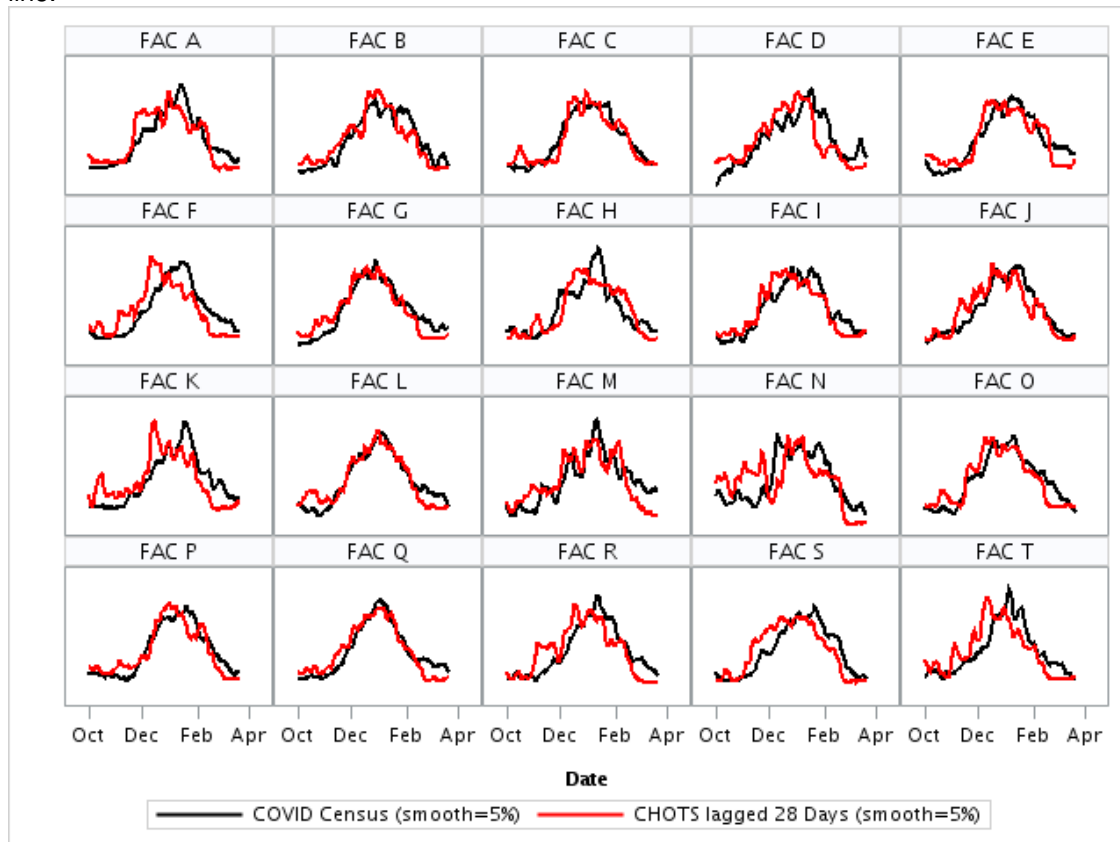
**Appendix Table 3. Example of CHOTS calculation for sample medical center.** The columns show a sample from Facility A indicating which of the statistical tests are significant (S) versus those which are non-significant (NS), as well as the contributing weight of the variable.

Variable	Baseline	Last	Slope	Score	Weight	Raw total
Cough/Cold Calls	S	S	NS	1	1	3.9
COVID Hospital Census	S	S	S	1.6	1	
ILI e-mail messages	NS	S	NS	0.6	1	
New COVID(+) tests	S	NS	S	0	1	
Respiratory infection visits	NS	NS	NS	0	0.5	
COVID-specific calls	S	S	NS	1	0.5	
COVID clinic visits	S	NS	NS	0	0.5	
COVID urgent visits	S	NS	NS	0	0.5	
Respiratory viral panel test	NS	NS	S	0.2	0.5	
Respiratory urgent visits	NS	NS	S	0.2	0.5	

**Appendix Figure 2a. Standardized values of the 28-day lagged COVID19 Hotspotting Score (CHOTS; red line) and COVID19 hospital census (black line) for each medical center from April 1, 2020 to September 30, 2020. Data are smoothed using a LOESS model. The smoothing parameter is the proportion of data in the local neighborhood: a value near 0 results in a curve that nearly interpolates the data whereas a value near 1 is nearly a straight line.**



**Appendix Figure 2b. Standardized values of the 28-day lagged COVID19 Hotspotting Score (CHOTS; red line) and COVID19 hospital census (black line) for each medical center from October 1, 2020 to March 21, 2021. Data are smoothed using a LOESS model. The smoothing parameter is the proportion of data in the local neighborhood: a value near 0 results in a curve that nearly interpolates the data whereas a value near 1 is nearly a straight line.**



**Appendix Table 4. Maximum Correlation between the COVID19-specific hospital census and lagged COVID19 Hotspotting Score across 7, 14, 21, 28, 35 and 42 Days at the Maximum Correlation**

Location	Maximum Correlation				Days at Maximum Correlation			
	Initial Period		Prospective Validation		Initial Period		Prospective Validation	
	CHOTS	Reduced CHOTS	CHOTS*	Reduced CHOTS†	CHOTS	Reduced CHOTS	CHOTS*	Reduced CHOTS†
<b>KPNC Region</b>	0.79	0.74	0.73	0.75	28	28	35	28
Facility A	0.78	0.71	0.66	0.59	28	14	28	35
Facility B	0.59	0.53	0.64	0.63	35	28	28	28
Facility C	0.56	0.48	0.76	0.78	28	14	21	21
Facility D	0.77	0.67	0.59	0.53	28	21	35	28
Facility E	0.65	0.52	0.69	0.71	28	35	21	21
Facility F	0.61	0.45	0.65	0.75	28	28	42	35
Facility G	0.72	0.66	0.71	0.74	35	35	28	28
Facility H	0.55	0.41	0.69	0.69	28	21	21	14
Facility I	0.73	0.64	0.67	0.69	35	28	35	28
Facility J	0.58	0.49	0.68	0.65	35	35	35	35
Facility K	0.62	0.55	0.63	0.74	28	28	35	28
Facility L	0.53	0.41	0.75	0.70	35	35	28	21
Facility M	0.43	0.19	0.51	0.60	14	7	28	28
Facility N	0.64	0.66	0.52	0.42	42	21	21	14
Facility O	0.74	0.70	0.72	0.72	35	35	28	28
Facility P	0.59	0.54	0.74	0.81	28	28	28	21
Facility Q	0.56	0.55	0.74	0.75	35	21	28	28
Facility R	0.77	0.68	0.60	0.57	14	14	35	35
Facility S	0.52	0.39	0.65	0.68	35	21	35	28
Facility T	0.73	0.78	0.68	0.70	21	14	35	42

\* Bold indicates validation value is greater than the development version of CHOTS

† Reduced CHOTS is based on all the same elements except for COVID calls, Cough and cold calls and ILI secure messages. Red indicates the value of the Reduced CHOTS is greater than the original CHOTS

#### Validation CHOTS

12 out of 20 facilities have a higher maximum correlation on validation than development and 10 have the highest correlation occurring at same or earlier time in the validation period compared to development. Five facilities show both a higher correlation at an earlier or same time on validation vs. development.

#### Reduced CHOTS

Most facilities showed the highest correlation with Census at a later day lag than the original CHOTS indicating its ability to predict a surge is slightly delayed when the COVID, Cough and Call calls and ILI secure message data is excluded from the score.