Role of physician perception of patient smile on pretest probability assessment for acute pulmonary embolism

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ABSTRACT

Background Many clinicians use a global visual interpretation of patient appearance to decide if a patient looks sick or not. For patients with suspected acute pulmonary embolism (PE), we tested the relationship between visual appearance of a happy patient facial affect and probability of PE+ on CT pulmonary angiography (CTPA).

Methods Eligible patients were selected by usual care to undergo CTPA, the criterion standard for PE+ or PE−. Prior to CTPA result, trained study personnel obtained physician pretest probability using the gestalt method (visual analogue scale, 0%–100%), the Wells score (0–12) and physicians' impression of whether the patient smiled during the initial examination (smile+). Patients' faces were also video recorded and analysed with an automated neural network-based algorithm (Noldus FaceReader) for happy affect.

Results Of the 208 patients enrolled, 27 were PE+ and smile+ was more frequent in patients with PE+ than PE−, a finding confirmed by the Noldus. The diagnostic sensitivity and specificity of smile was low, and physicians overestimated presence of an alternative diagnosis more likely to PE with smile+ than smile− patients in patients with true PE. As a result, the area under the receiver operating characteristic curve (AUROC) was lower for the Wells score in smile+ patients. However, the physicians' mean gestalt estimate of PE did not differ with smile status, nor did smile status affect the AUROC for gestalt.

Conclusions In patients with suspected PE, physician recollection of patients' smile+ was more common in PE+ patients, and was associated with a less accurate Wells score, primarily because physicians overestimated probability of alternative diagnosis. However, the overall diagnostic accuracy of physicians' gestalt did not differ with perceived smile status. These data suggest that the patients' smile had less effect on the numeric gestalt pretest probability assessment than on the binary decision about an alternative diagnosis.

Key messages

What is already known on this subject?
Clinicians frequently use the phrase 'He/she looks sick' to convey presence of illness.

What this study adds?
No evidence has tested the role of patient perception of a happy affect on the physician's assessment of pretest probability for a potentially life-threatening illness such as acute pulmonary embolism (PE). Here we show an unexpected association of patient smile with PE and that smile deteriorates the commonly used Wells score for pretest probability assessment of PE but not the gestalt method.

INTRODUCTION

This work addresses the question of whether or not patients' facial expressions (affect) influence physicians' estimate of the probability of acute pulmonary embolism (PE). We focus on the relationship between physicians' recall of smile and two methods of pretest probability assessment for PE. The first method is the unstructured, often referred to gestalt method of pretest probability assessment, and the second is a structured numerical scoring method derived from logistic regression analysis, known as the Wells score. Gestalt processing may be synonymous with the terms implicit estimate, clinical suspicion, clinical judgement or unstructured assessment. Gestalt assessment of pretest probability—and the subsequent diagnostic reasoning it yields—encompasses several domains, including expert intuition, heuristic processing and logic.[1 2] For acute PE, gestalt assessment has been found to be equally accurate as structured models, including the Wells score.[3] Of relevance, the Wells score requires the clinician to make a subjective, or gestalt binary decision of whether PE is the most likely diagnosis, and this component drives much of the diagnostic power rules.[4 5] Limitations of gestalt processing include the role of prior experience, and that its formulation process is hidden.[1 6] Part of that hidden process may include the physicians' observation of their patients' faces.

Prior literature suggests a relationship between the emotional state communicated by patients' facial expressions and cardiopulmonary health. In a former study, we analysed facial affect of ED patients being tested for PE, using the gold standard manual coding system to derive emotional states (the facial action coding system (FACS)[7]), and found that patients who had any serious cardiopulmonary diagnosis had less variability in affect and more negative emotions expressed, including absence of smile.[8] Others have interpreted 'sick' facial expressions as conveying negative emotions, including disgust, anger and contempt.[9] Forehead muscle tension increases in patients with more laborious breathing.[10] Facial expressions of patients with myocardial ischaemia had significantly more

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anger, non-enjoyment smiles and brow lowering than patients without myocardial ischaemia.[11 12] Patients with acute PE have evidence of acute neurohumoral stress responses, including rapid heart rate, leucocytosis, criteria for systemic inflammatory syndrome, elevated blood levels of lactate and even abnormal body temperature.[13] Taken together, these prior data and interpretations of the findings spur the hypothesis that patients with acute PE would be less likely to show a happy affect, primarily manifested as a smile during examination, than patients without PE.[14] As such, this is a study to demonstrate the impact of patients' affect on decision-making, and ostensibly its effect on pretest probability, which naturally affects test ordering and diagnosis. Accordingly, our objective was to examine physicians' perceptions of patients' smile in relation to the same physicians' gestalt estimation and Wells pretest probability of PE, and in relation to the result of CT pulmonary angiography (CTPA). Since this should in turn ultimately be related to anticipated diagnosis and test ordering, we also sought to explore the relationship of perceived patients' smile to the diagnosis of acute PE.

METHODS

This was a prospective, two-centre exploratory study of diagnostic accuracy drawn from an ongoing registry of patients undergoing CTPA scanning in the EDs of Wishard and Methodist hospitals in Indianapolis, Indiana, USA from October 2012 to June 2015. Both hospitals are urban academic centres with residencies in emergency medicine. This study had approval from the Indiana University School of Medicine Institutional Review Board and all patients signed an informed consent form. This work is the first to derive from that registry.

Participants

Potential participant patients were identified by an electronic email alert generated when a CTPA order was placed from the ED. Trained and experienced research personnel then approached the patients for informed consent. Exclusion criteria were known diagnosis of PE, inability to understand the informed consent process because of acuity of illness (eg, symptomatic arterial hypotension or severe respiratory distress), prior participation, intoxication, altered mental status, severe visual impairment or dementia or reasons to preclude follow-up.

Predictor variables

Research personnel approached patients as soon as practicable after CTPA was ordered to obtain informed consent from the patients and approach the clinician who ordered the CT scan to request two actions and answers to seven questions. The Research Assistant then interviewed the clinician who ordered the CT scan. Questions asked of the physicians included a query of results of other diagnostic tests known and planned by the clinician, the clinician's gestalt pretest probability for PE expressed on a visual analogue scale, the question 'Did the patient smile during their exam' and six additional questions: (1) suspect another diagnosis more likely, (2) use of empiric heparin (prior to imaging), (3) belief the patient had deep vein thrombosis (DVT), (4) presence of respiratory distress, (5) wheezing and (6) altered mental status. In all cases, patients were approached, and these questions were obtained prior to results of the CTPA scan. Additional clinical data were obtained from the patient and from the medical record and recorded in REDcap[15] and results were exported to a comma-separated values file for analysis.

Criterion standard for PE

All participants in this study underwent CTPA, and other testing was at the discretion of the clinical team. The criterion standard for PE+ required the board-certified radiologist to interpret a filling defect consistent with acute PE, or the patients to have a DVT diagnosed on the same day of enrolment. Patients without a filling defect and no DVT were PE−. All patients also had a 45-day telephone and medical record follow-up for venous thromboembolism outcome, but this was not used as part of the criterion standard.

Videos of patients' faces

Patient affect was assessed under controlled conditions with an objective face reading software for the purpose of comparing the results with clinicians' perception. As part of this registry, we also video recorded a convenience sample of patients' faces as they watched five visual stimuli on the laptop. These videos were also obtained prior to the results of CT scanning. Four of the visual stimuli were standardised still photos from the International Affective Picture Set (IAPS): three of which have been shown to elicit strong pleasant emotions from normal persons (baby, embrace, puppies) and one neutral to serve as a baseline (cup).[16] Patients also viewed a 26 s video clip from a 'Best of America's Funniest Home Videos' (a cat that flips after being taunted by a bird and an excited dog falling in a pool); this video was chosen based on the expectation that it should elicit a strong positive emotional response since it won awards as funniest videos in a nationwide voting. Each of the standardised IAPS images was projected for 4 s, separated by 1 s of a black screen. The patients' faces were recorded only when the image was projected. Patients were placed in semi-Fowler's position, and the camera of a small laptop computer (MacBook Air, Apple, Cupertino, California, USA) was positioned approximately 18 inches in front of the subject, while 20 white light emitting diodes on flexible struts were positioned to produce even lighting of the subject's face. The computer's webcam recorded participants' facial expressions. The computer was programmed using Mac OS X to demonstrate the six-slide presentation shown above. The *cup*, typically associated with a neutral response, is the control stimulus used to establish a baseline facial expression, and was always presented first. Videos were uploaded and analysed with the Noldus FaceReader, which is a software programme that electronically tags and monitors positioning of the patients' facial muscles and face features (eg, eyebrows, mouth). The FaceReader uses a neural network algorithm to specify and quantify the intensity of seven discrete emotions (ie, happy, sad, angry, fearful, disgusted, surprise and neutral) on a scale from 0 to 1 each 50 ms. The 'happy' emotion requires a smile in addition to other movements from the eyes and cheeks. Study associates then used these numbers to calculate the total number of happy and negative expressions shown by each patient as they watched all the stimuli. The Noldus FaceReader software has shown good internal reliability.[17]

Analysis

The primary question was the frequency of the perception of smile based upon PE outcome, and the apparent effect of the perceived smile on the mean gestalt pretest probability and frequency for estimate of an alternative diagnosis based upon presence or absence of smile. As an internal control of sensibility of clinician recall of smile, the frequency of smile was compared with the estimate of the presence of respiratory distress, use of empiric heparin and altered mental status, with the expectation that smile should be less common in patients with these features. As an additional control, we calculated the number of patients who expressed one or more instances of happy affect (detected on the Noldus FaceRreader), while patients watched the 26 s video. Group means and frequencies were compared with 95% CIs for their differences. Diagnostic accuracy of gestalt and the Wells score were assessed with the area under the receiver operating characteristic curve (AUROC). Statistics were performed on StatsDirect, V.3.30.158 (Cheshire, England). As an exploratory study, this had no formal sample size, although in general, we expected the need to enrol approximately 200–220 patients to have at least 20 patients with PE+ and thus narrow the 95% CI for diagnostic sensitivity to <10%.[18]

RESULTS

Patient characteristics

Figure 1 shows the flow diagram of enrolment. We enrolled 211 patients, with three who did not complete the CTPA scan within 24 hours because of elopement (n=1), technical problems (n=1) or change in clinical plan (n=1). Of the 208 patients with complete data and reference standard CTPA, 23 had PE+ diagnosed on CTPA and 4 had proximal (above knee) leg DVT diagnosed on formal ultrasonography, leaving 27/208 (13%, 95% CI 9% to 18%) with criterion standard PE+. All 27 patients were treated with systemic anticoagulation. Although not part of the criterion standard, no patient had other imaging evidence outside of CTPA scanning for PE (eg, high probability scintillation lung scan or magnetic resonance pulmonary angiography) within 1 week of enrolment, but within 45 days, 2/181 (1%, 0% to 4%) additional patients, not initially classified as PE+, indicated they were diagnosed with PE on telephone follow-up. Physicians comprised 106 unique persons and were residents in 106 (51%) cases and board-certified emergency physicians (faculty) in 102 (49%) cases. Videos for analysis by the Noldus FaceReader were available for 145 patients, including 10 with PE+; the FaceReader data were not available for all patients, primarily due to poor video quality, which interfered with the ability of the software to analyse the face data (eg, poor lighting).

Table 1 shows selected clinical characteristics of the population, stratified by PE diagnosis. The table compares means and frequencies between PE+ and PE−, and demonstrates patients with PE+ tended to be less likely to be female, less likely to have an alternative diagnosis, had a higher gestalt pretest probability and were more likely to receive empiric heparin, cause a plan to image for DVT and have altered mental status. Additionally, patients with PE+ were more often perceived as having smiled by clinicians (63% with PE+ vs 40% with PE−, 95% CI for difference of 23%=3% to 41%). We found no difference in the rate of smile+ recall between resident and faculty physicians: residents 41% overall, 57% PE+, 39% PE−; faculty: 44% overall, 69% PE+, 41% PE−.

Association of smile and perception of PE risk

Table 2 stratifies gestalt pretest probability, the Wells score and probability of an alternative diagnosis based upon the physicians' recall of whether the patient smiled or not. First, the physicians' estimate of gestalt pretest probability was not significantly different between smile+ and smile−, suggesting a delinking of gestalt processing from perception of smile. However, physicians had a much greater tendency to characterise smile+ patients as having an alternative diagnosis more likely. These observations suggest greater independence with prediction of the numeric gestalt pretest probability for PE than for the binary assessment of its probability relative to competing (and potentially more benign) diagnosis.

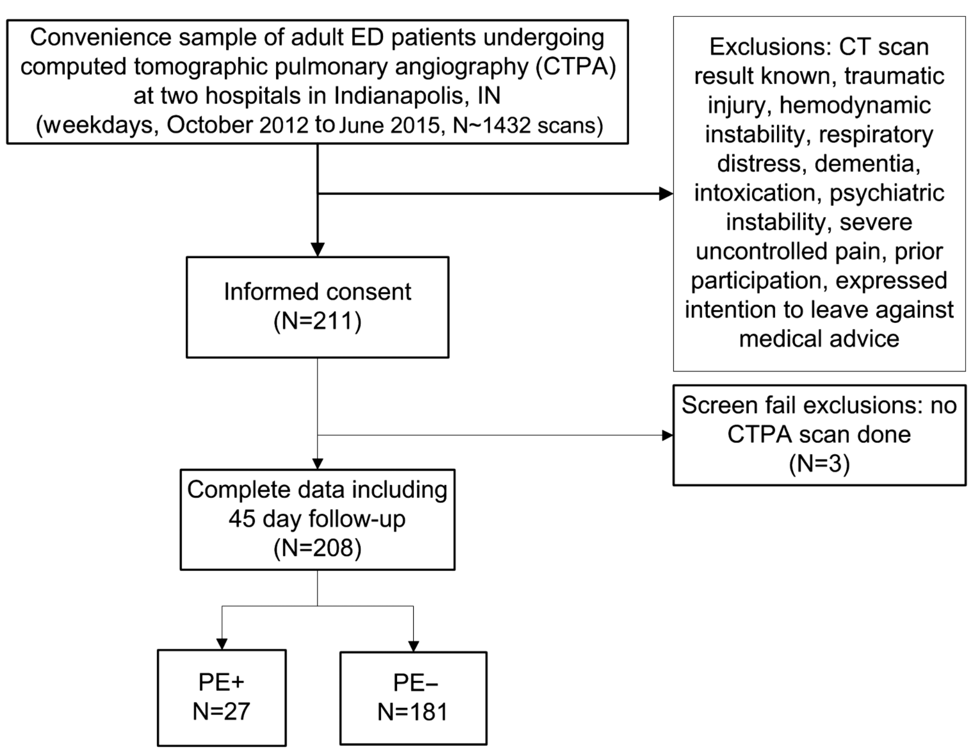

Figure 1 Flow diagram of patient enrolment. The authors did not track the precise number and reasons why patients were not enrolled, nor the number of patients who were never screened because of availability of research personnel.

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Table 1 Clinical characteristics of patients

Characteristic	PE+ (n=27) Mean or N	PE+ (n=27) SD or %	PE− (n=181) Mean or N	PE− (n=181) SD or %	Combined (N=208) Mean or N	Combined (N=208) SD or %
Age (years)	53	13	50	16	50	0.16
Heart rate (bpm)	95	21	95	18	95	19
Systolic BP (mm Hg)	135	27	139	28	137	28
SpO_2	97	3	96	6	96	6
RR (breaths/min)	17	4	19	4	19	4
Female gender	14	52%	118	64%	132	63%
White race	18	67%	94	51%	112	54%
Chief complaint dyspnoea	13	48%	76	42%	89	43%
Chief complaint chest pain	7	26%	78	43%	85	41%
No known prior medical problems	4	15%	22	12%	26	13%
Prior venous thromboembolism	11	41%	62	34%	73	35%
Chronic obstructive pulmonary disease	3	11%	33	18%	36	17%
Prior coronary artery disease	3	11%	32	17%	35	17%
Active malignancy	3	11%	12	7%	15	7%
Pregnant	0	0%	10	5%	10	5%
Post partum <1 week	0	0%	11	6%	11	5%
CTPA in past 6 months	4	15%	37	20%	41	20%
Patient smiled during exam	17	63%	72	40%	89	43%
Gestalt pretest probability	43	24	29	22	72	35%
Wells score	2.8	2.1	1.6	1.7	4.4	2%
Alternative diagnosis more likely	12	44%	123	68%	135	65%
Respiratory distress	2	7%	41	23%	43	21%
Empiric heparin given	3	11%	3	2%	6	3%
Plan to image for deep vein thrombosis	10	37%	22	12%	32	15%
Altered mental status	4	15%	3	2%	7	3%

CTPA, CT pulmonary angiography; PE, pulmonary embolism.

Table 2 Comparison of physicians' assessments based upon perception of patients' smile

	Physicians' estimate of smile status				
	Smile+ (n=87)		Smile− (n=121)		
Physicians' assessment	Mean or N	SD or %	Mean or N	SD or %	95% CI for difference
Gestalt pretest probability (%, 0–100)	29	24	32	21	−9.3 to 3.3
Wells score (0–14)	3.1	2.1	5.7	2.0	−3.2 to −2.0
Alternative diagnosis more likely	61	70%	45	37%	19% to 45%

The overall diagnostic accuracy of gestalt did not vary based on smile recall (figure 2A), but the diagnostic accuracy of the Wells score varied significantly with smile recall (figure 2B). For all gestalt estimates, the AUROC curve=0.70 (95% CI 0.60 to 0.80) which when subdivided into smile+ versus smile− patients did not differ (smile+: 0.71, 95% CI 0.57 to 0.85, smile−: 0.71, 95% CI 0.57 to 0.85). For all Wells score values, the AUROC curve=0.67 (95% CI 0.55 to 0.79) which when subdivided into smile+ versus smile− patients was lower for smile+ (0.58, 95% CI 0.42 to 0.73) than smile− (0.85, 95% CI 0.74 to 0.96). To further illustrate this finding, figures 3 and 4 plot the mean (SD) gestalt pretest probability and the frequency of alternative diagnosis more likely than PE, respectively, based upon smile and PE groupings. Online supplementary table S1 shows that physicians' recall of smile performed poorly as a binary diagnostic test, resulting in a sensitivity and specificity of 37% and 40%, respectively when smile− is treated as test+.

Association of smile and chest pain

Because pain might influence likelihood of smiling, we examined the effect of the most common cause of pain, chest pain (N=85 total) on probability of smile. We defined chest pain as present if it were the primary complaint, which included 85 patients, including substernal pain (n=25) or pleuritic pain (n=60). Nine other patients had a pain-related primary complaint, five with limb pain, two with back pain and two with abdominal pain. The proportion of patients with chest pain who smiled was 33/85 (39%), compared with 56/123 (46%, 95% CI for difference=−20% to 7%) who smiled with other primary complaints. Thus, chest pain did not have a profound influence on probability of smile recall.

Noldus FaceReader results

To provide an objective comparator about presence or absence of patients' smile, we included the computerised Noldus

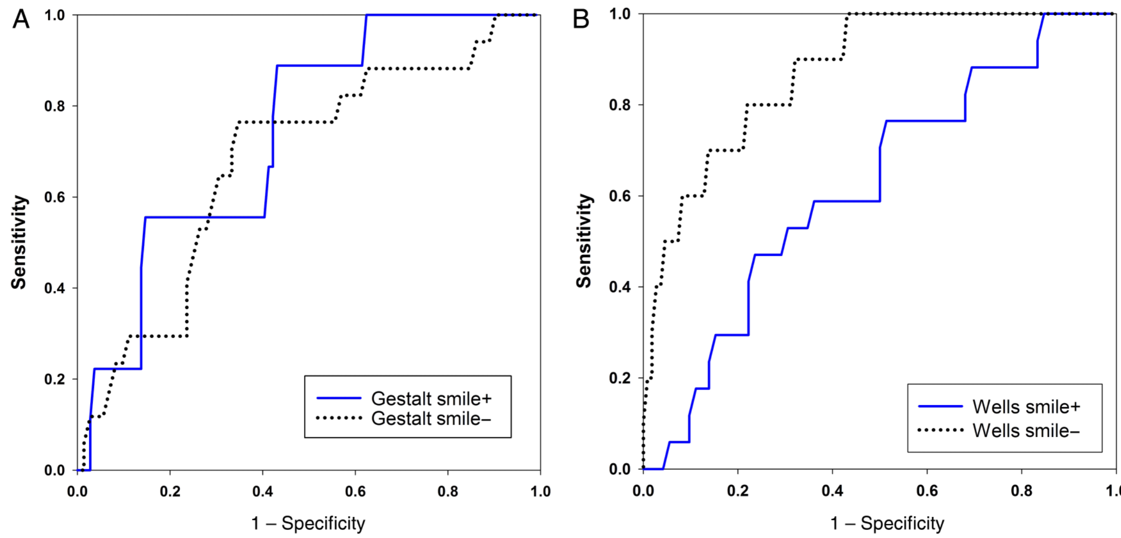

Figure 2 (A) Receiver operating characteristic curves for the gestalt pretest for patients whose physicians thought smiled (smile+) or not (smile–) during their initial evaluation. Area under the curves: gestalt smile+ 0.705 (95% CI 0.565 to 0.845), gestalt smile– 0.710 (0.567 to 0.852). (B) Receiver operating characteristic curves for the Wells score for patients whose physicians thought smiled (smile+) or not (smile–) during their initial evaluation. Area under the curves: Wells smile+ 0.576 (0.423 to 0.730), Wells smile– 0.851 (0.740 to 0.964).

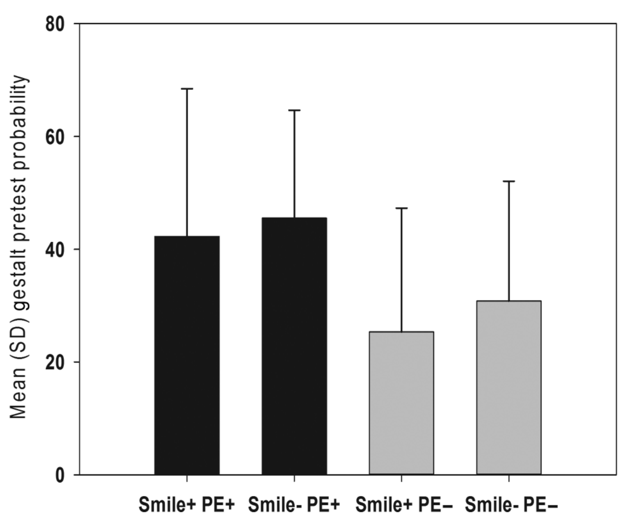

Figure 3 Gestalt pretest probability assessment stratified by pulmonary embolism diagnosis and smile status.

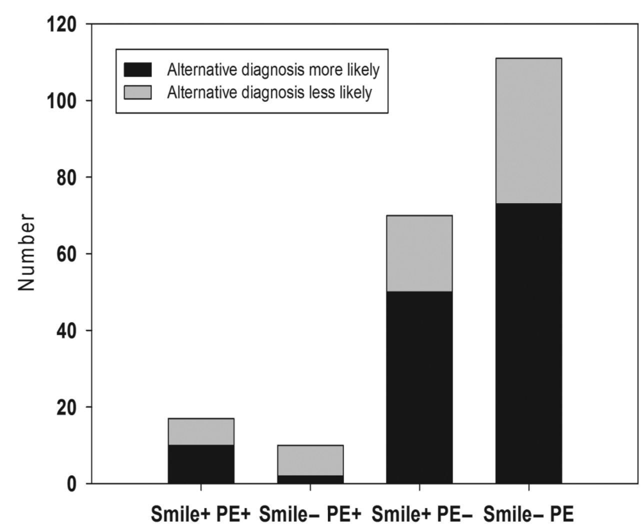

Figure 4 Alternative diagnosis assessment stratified by pulmonary embolism diagnosis and smile status.

FaceReader. Online supplementary table S2 shows a 2×2 contingencies for the Noldus FaceReader assessment of a happy affect (which requires a smile), while patients watched the humorous video and the physicians' perception of smile during the examination. The overall agreement was 58% and Cohen's Kappa was 0.16 (95% CI 0.05 to 0.31). Similarly, online supplementary table S3 shows the Noldus assessment of happy affect based upon PE status; similar to the clinicians' recall of smile, Noldus found 60% of patients with PE had a happy affect. Similar to physicians, the Noldus categorised more PE+ patients as smile+ than PE– patients as smile+ (6/42 (14%) versus 4/103 (4%), 95% CI for difference 1% to 24%.

DISCUSSION

In daily practice, many clinicians use the phrase 'He/she looks sick' or 'He/she does not look sick' to describe their patients, yet this fundamental mode of deciding and then communicating the presence of acute illness has almost no published evidence to support its use.[8] Based primarily upon experience, we believe patient affect may be one factor from the physical examination that contributes to physicians' assessment of sickness. For the first time, we show a potential cause-effect relationship between patient affect and physicians' decision-making, in this case for a potentially fatal disease, acute PE. Extrapolating from work showing increased frowning and anger in patients with symptomatic coronary stenosis, we anticipated a lower prevalence of happy affect among PE+ patients.[11 12] However, our findings were counterintuitive to our hypothesis, namely because the clinicians' recall of their patients' affect as having shown a smile was more common in PE+ patients. The finding of smile+ more common in PE+ was also supported by the automated face recognition software as patients watched a humorous video.

Explanations for this surprising finding could include the fact that smiles were not authentic representations of happy emotions. Physicians were only asked to report whether or not the patient smiled; they were not asked to make the subtle distinction of how genuine the smile was or if they thought the patient appeared happy. Ambadar *et al*[19] note that smile types include amused (also called happy, felt, Duchenne, enjoyment, genuine, humour, duplay and broad), polite and embarrassed (also called non-Duchenne, unfelt, non-enjoyment, false, social, masking, and controlled), tickling, and pain smiles. Ekman and Friesen refer to several types of false smiles including the 'masking smile' made in attempt to conceal strong negative emotion by appearing to feel positive.[20] Thus, it is possible the smiles recalled by clinicians were truly representing nervousness, anxiety or the so-called stress smile or possibly out of obligatory politeness.[21] With respect to the Noldus output, this device is not designed to differentiate authentic versus feigned emotions. This may explain why our prior study, which used manual facial affect coding (FACS) to analyse patients' facial expressions, did not find patients with cardiopulmonary emergencies to express more happy expressions than patients without an emergent diagnosis.[8] However, only two patients in that study had PE+. Trained FACS coders rely on certain combinations of facial muscles to help identify emotions, which make it a very sensitive method to detect emotional subtleties. Another possibility is that the PEs experienced by these patients produced minimal physiological stress (eg, no vital sign measurement was significantly different between PE+ and PE−). Or, it is possible that patients with PE were truly happy that their concerns were being taken seriously, despite physiological distress they may have been experiencing.

These data show an association between physicians' perception of patients' smile and assessment of pretest probability for PE using the Wells criteria. In particular, clinicians who perceived smile+ appeared to have an impaired ability to decide on the presence or absence of an alternative diagnosis as shown in figure 4. Indeed, the overall diagnostic accuracy of the Wells score, assessed by the AUROC was 30% lower in patients with smile+ compared with smile−. However, this effect was not observed with the gestalt method, which had identical AUROC. The differential impact of the smile on these two forms of physicians' diagnostic impression suggests that the ability to give a numeric value for pretest probability marked on a visual analogue scale is less influenced by the smile than when physicians are asked to make a binary assessment. Thus, patients' smile may elicit a stronger framing heuristic when clinical impression is expressed as a binary decision than when it is expressed on a continuous scale.[22] We can make no inference about causation; however, the results justify the time and cost of more rigorous research to determine the extent to which clinicians use their patients' faces to make decisions.

This work has strengths and weaknesses. Strengths include efforts to minimise reference bias by collecting pretest probability and affect data prior to knowledge of CTPA results. All patients had CTPA, which is widely regarded as the most accurate clinically available diagnostic test for PE.[23] Additionally, we had 45-day follow-up which demonstrated 2/181 additional patients having PE, both had good quality CT scans that were negative for PE at enrolment. We believe these patients developed PE that was not present on the day of enrolment. The Noldus FaceReader system provided independent confirmation of increased likelihood of smile from real-time videos of 145 patients. However, we point out that the patients were recorded between 15 and 30 min after the physicians assessed the smile status, and patients were watching a stimulus intended to elicit a smile or laugh. These differences may account for the 42% rate of disagreement between physicians and the Noldus assessment of smile. Additionally, physicians had to retroactively recall whether or not a patient smiled during their assessment, so there may be some recall bias or error. Other weaknesses include that we excluded patients who had severe respiratory distress or overt circulatory shock leaving a more low to moderately ill sample. Also data are from two hospitals in a single city and the sample size is moderate. As such, we believe our results of smile+ recall as more frequent in patients with PE+ should be considered preliminary.

CONCLUSION

In patients tested for PE, physicians' recall of patients' smile was unexpectedly more common in patients with PE diagnosis. Clinicians were more likely to assign patients who smiled an alternative diagnosis to PE, and the accuracy of the Wells score was lower in patients who smiled. However, accuracy of numeric gestalt pretest probability estimate was not affected by smile status. More research should be conducted to better understand the connection between patient affect and how physicians formulate belief patterns of diagnostic certainty.

Contributors JAK conceived the study, wrote the protocol and assisted in data collection, performed data analysis and wrote the manuscript draft; DN, CLH and JC assisted with protocol development, data collection, analysis and participated in manuscript writing and revision. All authors approved the final version of this manuscript.

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Competing interests JAK is a consultant to Diagnostica Stago and has received grant funding from Roche Diagnostics. DN is the founder of EmotEd through which she receives funds from the National Institutes of Health Small Business Technology Transfer Research grant for her intellectual property and her role with this company. This company is developing an intervention to improve emotional awareness after traumatic brain injury.

Patient consent Obtained.

Ethics approval Indiana University School of Medicine Institutional Review Board.

Provenance and peer review Not commissioned; externally peer reviewed.

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