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Does A Diagnostic Algorithm Reduce the Overuse of Chest CT Angiography in Suspected Pulmonary Embolism? : A Pre- and Post-Intervention Retrospective Study in a Critical Access Hospital

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ORIGINAL RESEARCH

Implementing a Diagnostic Algorithm to Reduce Overuse of Chest CT Angiography for Suspected Pulmonary Embolism: A Retrospective Study in a Critical Access Hospital

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Introduction: Pulmonary embolism (PE) is a common, potentially fatal condition. Computed tomographic pulmonary angiography (CTA) is a standard method for diagnosing PE, but it carries risks for patients. We sought to minimize overuse of chest CTA by implementing a diagnostic algorithm to evaluate the likelihood of PE and the need for CTA.

Methods: A retrospective review of medical charts was performed for patients suspected of PE 3 months before and after implementing a diagnostic algorithm and educational intervention. Patients who underwent either D-dimer testing or a chest CTA were included. Patients were excluded if D-dimer testing was performed for suspected deep vein thrombosis (DVT) alone or if the chest CTA was performed for other reasons. Patients were divided into 3 groups of probability based on their Wells scores. Algorithms from the American College of Physicians (ACP) indicated next steps.

Results: A total of 414 patients were included in the study: 236 (57%) pre-intervention and 178 (43%) post-intervention. The mean age was 51 years (SD = 19.17). A total of 168 CTAs were performed, diagnosing PE in 11 patients (15%). D-dimer testing significantly increased after the intervention (80.9% vs 89.3%, *P* = .019), particularly in the low-probability group. D-dimer testing increased among patients in the low-probability group who met Pulmonary Embolism Rule-Out Criteria (PERC) (80.3% vs 97.17%, *P* = .001). Ordered chest CTAs were 11% less in the post-intervention versus pre-intervention groups (45.3% vs 34.3%, *P* = .023).

Conclusions: Implementing a diagnostic algorithm significantly reduced the use of CTA for suspected PE.

Keywords: pulmonary embolism, chest imaging, D-dimer, diagnostic algorithm

Pulmonary embolism (PE) is a common and potentially fatal disease, with an annual incidence of 112 cases per 100,000 in the United States. The incidence doubled in the 1990s after the introduction of D-dimer testing and computed tomographic pulmonary angiography (CTA).[1] Although CTA is the gold standard for diagnosis, it carries risks for patients, including ionizing radiation exposure, contrast-induced nephropathy, and contrast-induced anaphylaxis.[2]

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Limiting overuse of chest CTA in patients with a low clinical probability of PE was 1 of the 5 priorities of the Choosing Wisely health campaign by the American Thoracic Society and American College of Chest Physicians.[3] Studies have shown that implementing algorithms to risk-stratify based on Wells criteria, qualitative D-dimer testing, and Pulmonary Embolism Rule-Out Criteria (PERC) is a safe way to avoid unnecessary use of diagnostic CTA.[4-7] In 2015, the American College of Physicians (ACP) issued the best practice guideline for evaluating patients with suspected acute PE to determine whether a chest CTA was appropriate. The ACP recommendations were based on using the highly validated Wells score along with D-dimer levels or PERC.[8] Based on the

Wells score, the patient is initially categorized as at low, intermediate, or high-risk of having PE. A patient with a low probability of having PE would have PERC criteria assessed to determine the need for D-dimer testing. If the D-dimer is positive, the patient should undergo a chest CTA to rule out PE. A patient with an intermediate probability of having PE should only have a chest CTA performed if the D-dimer is positive. Finally, a patient with a high probability of having PE should undergo a chest CTA without D-dimer testing (Figure 1).

Despite increasing national awareness of the Choosing Wisely Campaign, recent studies still show a lack of using clinical decision rules to evaluate suspected PE patients in the clinical setting.[9-10] Similarly, our community hospital, Redington-Fairview General Hospital (Skowhegan, ME), saw an increasing use of chest CTA in suspected PE patients in recent years. Concern of this use led to our pilot study in 2017, in which we collected data from patients who underwent chest CTA during a 3-month period. Our pilot study showed that 25% of patients who underwent chest CTA for suspected PE did not have an indication based on their Wells score, PERC criteria, or D-dimer levels. Furthermore, based on the algorithm, 36% of the patients should have undergone D-dimer testing before a chest CTA was ordered. If the D-dimer was negative, chest CTA would not have been indicated in this group of patients (Appendix S1).

In this study, we sought to minimize the overuse of chest CTA at our local hospital by implementing a diagnostic algorithm and educational intervention for PE.

METHODS

Study design and setting

This study was conducted at Redington-Fairview General Hospital (RFGH) in Skowhegan, Maine. RFGH is an independent critical access hospital in rural Maine that provides care primarily for Maine residents in Somerset County. RFGH complies with the Center for Medicare and Medicaid rules for critical access hospitals, with the regulatory requirement of 25 inpatient beds and an annual average stay of ≤96 hours in inpatient acute care (excluding swing bed services).[11] RFGH has an average of 1,200 acute admissions and 21,000 emergency department (ED) visits annually. There are approximately 50 full-time providers, including 17 ED providers, 4 hospitalists, and 18 primary care providers.

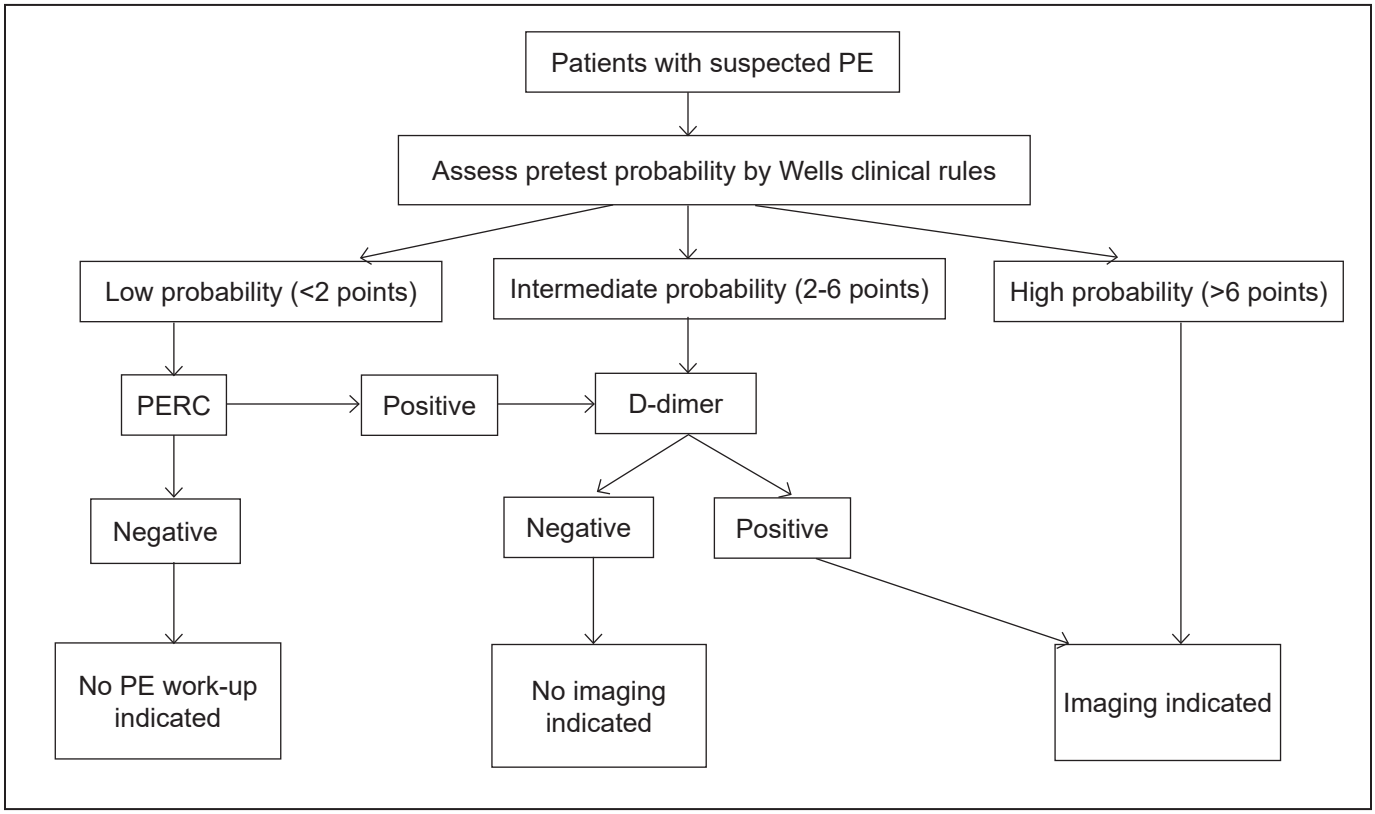

Figure 1. Pathway for evaluating patients with suspected PE[6]
PE, pulmonary embolism; PERC, Pulmonary Embolism Rule-Out Criteria.

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We conducted a retrospective review of electronic medical charts of adult patients who presented to the hospital with suspected PE. The study population included patients who underwent either D-dimer testing or chest CTA for suspected PE during the study period. We collected data over 3 months in late 2017 (pre-intervention) and compared them to a 3-month period in 2018 (post-intervention), 6 months after implementing the diagnostic algorithm and educational intervention. Our study was approved as a quality improvement project by the hospital executive committee.

Intervention

Before this study, we conducted a pilot study in which we collected data on the use of chest CTA in our hospital for patients with suspected PE (Appendix S1). We found that if we had followed the diagnostic algorithm based on the ACP guidelines, we could have prevented 25% of the total number of chest CTAs performed. We presented this result in a hospital-wide medical staff meeting in late 2017.

After the presentation, we proceeded with the education intervention by distributing the ACP algorithm via emails. One month later, we discussed the appropriate use of ACP guidelines in a medical staff meeting. Our primary focus was the ED because, based on our pilot study, most of the overuse occurred in the ED (90%). Therefore, during the ED monthly meeting, all ED providers were educated to ensure they were aware of the diagnostic algorithm. Furthermore, the ED director made the diagnostic algorithm visible and freely available to every provider in the ED in late 2017.

Study participants and data collection

We obtained lists of all patients who had D-dimer testing with our laboratory department and who underwent chest CTA from our radiology department. These patients were seen within 3 months before the intervention (pre-intervention) and within 3 months after the ACP algorithm was implemented with the educational intervention for 6 months (post-intervention). The patient lists were consolidated into a final list for data collection. Only adults were included in our study. Patients who had either D-dimer testing or a chest CTA for reasons other than suspected PE (i.e., deep vein thrombosis, aortic dissection, abnormal vasculature in the chest) were excluded. If there were no specific reasons indicated in the chart, suspected PE was assumed.

The patients' baseline characteristics (sex and age), clinical presentation [(including chief concerns and initial vital signs (systolic blood pressure, heart rate, and oxygen saturation)], as well as important laboratory data were collected. The Wells criteria were used to assess pretest probability. Data collection was done via the online survey software Qualtrics®. The Wells score (Appendix S2) and PERC (Appendix S3) were calculated individually by the software based on the corresponding questions during data collection. Depending on the Wells score, patients were divided into 3 categories of probability: low-probability (<2), intermediate-probability (2-6), and high-probability (>6). The algorithms from the ACP were used to determine the next step of management, including calculating PERC from the initial presentation and measuring the D-dimer if indicated per the algorithm (Figure 1). Although the ACP advocates for using an age-adjust D-dimer level, we did not apply this recommendation in our study.

Statistical analysis

Chi-square test was used to examine the statistical significance of numbers from D-dimer testing and chest CTA between the pre- and post-intervention groups. Logistic regression was used to calculate the effect estimate. All reported confidence intervals (CIs) are two-sided 95% intervals, and tests were done at the two-sided 5% significance level. Stata 14.2 (Stata Corp, College Station, Texas) was used for all analyses.

RESULTS

We reviewed electronic medical records of 455 patients who had either D-dimer testing or chest CTA performed during the 3-month pre- and post-intervention periods. We excluded 31 patients (7%) who had workups for clinically suspected deep vein thrombosis (DVT), 6 (1%) due to incomplete records, and 4 (1%) who underwent chest CTA for other reasons. A total of 414 patients were included in our study, 236 (57%) pre-intervention and 178 (43%) post-intervention. Of these, 57% were female. Ages ranged from 10 to 95 years, with a mean age of 51 years (SD = 19.2). The mean age of pre-intervention patients was 48.8 years (SD = 19.3) compared to 54.6 (SD = 18.5) in post-intervention patients (P = .002). Most patients were from the ED (95%). The most common chief concerns were chest pain (48%) and shortness of breath (32%). There was no significant difference in the chief concerns and vital signs (e.g., blood pressure, heart rate, oxygen saturation) on initial presentation for both pre- and post-intervention patients (Table 1).

After categorizing patients into pretest probability groups based on their Wells score, we found that there were 206 (87.3%) vs 141 (79.2%) patients in the low-probability group, 29 (12.3%) vs 35 (19.7%) in the intermediate-probability group, and 1 (0.4%) vs 2 (1.1%) in the high-probability group pre- and post-intervention, respectively. D-dimers were tested in 81% of patients pre-intervention compared to 89% post-intervention, showing a significant increase in the use after post-intervention (OR 1.97, CI 1.11 to 3.51, *P* = .021) (Table 2). A total of 168 CTAs were performed, with an overall reduction in the use of CTA post-intervention (34.27% vs 45.34%; OR 0.63, CI 0.42 to 0.94, *P* = 0.024). Of the 168 patients who underwent CTA, 11 (15%) had pulmonary emboli (9 pre-intervention and 2 post-intervention). PE was found in 5 patients (5/347; 1.4%) in the low-probability group, 5 (5/64; 7.8%) in the intermediate-probability group, and 1 (1/3; 33%) in the high-probability group. The overall incidence of PE in our study was 2.65%. Lung ventilation/perfusion scan (V/Q scan) was done in 2 patients in the intermediate group post-intervention.

We found that within the low-probability groups, there was a significant decrease in CTAs performed post-intervention compared to pre-intervention (29.08% vs 43.20%; OR 0.54, CI 0.34 to 0.85, *P* = .008) (Table 3). Furthermore, D-dimer testing increased within the low-probability group post-intervention compared to pre-intervention (97.16% vs 83.50%; OR 6.77, CI 2.35 to 19.54, *P* < .001) (Table 4). There was no difference within the intermediate- and high-probability groups.

We performed subgroup analysis in negative D-dimer patients and negative PERC patients in the low-probability group. In the subgroup of patients with a negative D-dimer, there was no significant difference in the number of CTAs pre- and post-intervention (Tables 5). When we applied the PERC criteria in the low-probability group to the analysis, the use of chest CTA decreased and D-dimer testing increased from pre- to post-intervention in the subgroup of negative PERC patients, although these findings were not statistically significant (Table 6). There was no PE diagnosed in patients in the PERC-negative group.

DISCUSSION

Our study found that implementing a diagnostic algorithm for the evaluation of PE significantly reduced the use of chest CTA in our community hospital. This change seemed to result largely from the appropriate use of the D-dimer test, particularly for patients in the low-probability group. In previous studies, the Wells score and PERC criteria were well-validated, which helped to minimize improper testing. Using ACP's diagnostic algorithm was feasible and effective in reducing the number of unnecessary CTAs in the evaluation of PE.

There are limitations to this study. First, the number of patients suspected for PE post-intervention was less than pre-intervention, even though the number of ED visits were not different between the two periods (5520 pre-intervention vs 5329 post-intervention). This difference might reflect that providers had increased awareness of the overuse of chest CTA from the pilot study and educational intervention. This awareness might have increased their reluctance to order a chest CTA or D-dimer for patients with low suspicion of PE. We did not include such patients in our study because we retrospectively collected data of patients who underwent CTA and/or D-dimer testing. However, despite the difference in population size between the pre- and post-intervention groups, the baseline characteristics, chief concerns, and vital signs were comparable. Furthermore, the incidence of PE between the groups was not different. If this reasoning is correct, and we had collected all patients suspected of PE, our study would have been more robust, and the effect estimate further from null.

Second, the nature of a retrospective study poses the risk of bias. For example, all electronic medical records were reviewed by the authors, none of whom were directly involved in the cases. The judgement of ordering the test could be different based on individual reasoning and clinical experience. The Wells score allows a significant opportunity for clinical gestalt, with 3 points assigned if the PE may be more or equally likely than other diagnoses. This reasoning is nearly impossible to ascertain from a retrospective chart review, unless the data is specifically recorded by providers. Furthermore, accurately determining the Wells score depends on detailed documentation of the history and physical exam. Poor charting and unavailability of information may have impacted these calculations.

Third, the incidence of PE in our study was relatively low (11/414, 2.65%) compared with other studies.[12] We believe that this result could be because most of our cohort (84%) was in a low-probability group that typically had a low incidence of PE.[13] With the relatively low incidence and small sample size in our study, we had a limited ability to detect misdiagnosis of PE.

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Table 1: Baseline characteristics of pre- and post-intervention groups

Characteristic	Pre-intervention (n=236)	Post-intervention (n=178)
Mean age (SD)	48.8 (19.3)	54.6 (18.5)
Sex		
Female	142 (60.2%)	94 (52.8%)
Male	94 (39.8%)	84 (47.2%)
Departments		
ED	226 (95.8%)	168 (94.4%)
Inpatient	6 (2.5%)	4 (2.3%)
Outpatient/Clinic	4 (1.7%)	6 (3.4%)
Systolic blood pressure < 90	7 (3.0%)	7 (3.9%)
Heart rate > 100	69 (29.2%)	61 (34.3%)
Oxygen Saturation < 88%	24 (10.2%)	17 (9.6%)
Shortness of breath	78 (33.1%)	55 (30.9%)
Chest pain	119 (50.4%)	83 (46.6%)
Median Wells score (IQR)	0 (0,1.5)	1 (0,1.5)
Pretest probability group		
Low	206 (87.3%)	141 (79.2%)
Intermediate	29 (12.3%)	35 (19.7%)
High	1 (0.4%)	2 (1.1%)
Median PERC score (IQR)	1 (0,1)	1 (0,1)
D-dimer done	191 (80.9%)	159 (89.3%)
Mean D-dimer level (SD)	0.844 (1.809)	0.916 (1.719)
Positive D-dimer	69 (36.1%)	58 (36.6%)
CTA done	107 (45.3%)	61 (34.3%)
Diagnosis of PE	9 (8.4%)	2 (3.3%)

CTA, computed tomographic pulmonary angiography; ED, emergency department; IQR, interquartile range; PE, pulmonary embolism; PERC, Pulmonary Embolism Rule-Out Criteria; SD, standard deviation.

Table 2: Comparison of CTAs and D-dimer testing performed in patients suspected of PE

Year	CTA Performed		OR (95%CI)	P value	D-Dimer Performed		OR (95%CI)	P value
	Yes	No			Yes	No		
Pre (n=236)	107 (45.34%)	129 (54.66%)	0.63 (0.42 to 0.94)	0.024	191 (80.93%)	45 (19.07%)	1.97 (1.11 to 3.51)	.021
Post (n=178)	61 (34.27%)	117 (65.73%)			159 (89.33%)	19 (10.67%)		

CTA, computed tomographic pulmonary angiography; OR, odds ratio; PE, pulmonary embolism; Pre, pre-intervention; Post, post-intervention; SD, standard deviation.

Table 3. Comparison of CTA performed in suspected PE pre- and post-intervention, stratified by pretest probability.

Pretest probability group*	CTA Performed		OR (95% CI)	P Value
	Pre (n = 107)	Post (n = 61)		
Low (n = 130/347, 37.46%)	89/206 (43.20%)	41/141 (29.08%)	0.54 (0.34 to 0.85)	.008
Intermediate (n = 37/64, 57.81%)	18/29 (62.07)	19/35 (54.29)	0.76 (0.27 to 1.98)	.53
High (n = 1/3, 33.33%)	0/1 (0%)**	1/2 (50%)***	NA	NA

*Denominator is the total number of patients in corresponded groups
**Patient transferred from ED
***CTA was not done in one patient due to unlikely PE per ED provider (diagnosis was COPD exacerbation)
Note: CTAs indicated PE as shown below.
Pre: Low = 5/89 (6%), Intermediate = 4/18 (22%)
Post: Low = 0/41 (0%), Intermediate= 1/19 (5%), High = 1/1 (100%)

COPD, chronic obstructive pulmonary disease; CTA, computed tomographic pulmonary angiography; ED, emergency department; NA, not applicable; OR, odds ratio; PE, pulmonary embolism; Pre, pre-intervention; Post, post-intervention..

Table 4. Comparison of D-dimer testing performed in suspected PE stratified by pretest probability.

Pretest probability group*	**D-Dimer Performed**		**OR (95% CI)**	***P* Value**
	Pre (n = 191)	**Post (n = 159)**		
Low (n = 309/347, 89.05%)	172/206 (83.50%)	137/141 (97.16%)	6.77 (2.35 to 19.54)	< .001
Intermediate (n = 40/64, 62.5%)	18/29 (62.07%)	22/35 (54.29%)	1.03 (0.37 to 2.86)	.95
High (n = 1/3, 33.33%)	1/1 (100%)	0/2 (0%)	NA	NA

*Denominator is the total number of patients in corresponded groups
Note: D-dimers were positive as shown below
Pre: Low = 55/172 (32%), Intermediate = 13/18 (72%), High = 1/1 (100%)
Post: Low = 46/137 (34%), Intermediate = 12/22 (55%)

OR, odds ratio; PE, pulmonary embolism; NA, not applicable; Pre, pre-intervention; Post, post-intervention.

Table 5. Comparison of CTAs performed in patients with a negative D-dimer.

Pretest Probability Group with Negative D-Dimer	**CTA Performed**		**OR (95% CI)**	**P Value**
	Pre (n = 122)	**Post (n = 101)**		
Low (n = 208)	12/117 (10.26%)	4/91 (4.40%)	0.40 (0.13 to 1.29)	.126
Intermediate (n = 15)	0/5 (0.00%)	1/10 (10.00%)	NA	NA

Notes:
No patients in the high-probability group had a negative D-dimer.
No PE in all patients with a negative D-dimer.

CTA, computed tomographic pulmonary angiography; OR, odds ratio; PE, pulmonary embolism; NA, not applicable; Pre, pre-intervention; Post, post-intervention.

Table 6. Comparison of CTAs and D-dimer performed in suspected PE in a group of negative PERC.

Year	CTA Performed		OR (95%CI)	P Value	D-Dimer Performed		OR (95%CI)	P Value
	Yes	No			Yes	No		
Pre (n = 74)	18 (24.32%)	56 (75.68%)	0.29 (0.08 to 1.07)	.06	66 (89.19%)	8 (10.81%)	4.12 (0.49 to 34.32)	1.31
Post (n = 35)	3 (8.57%)	32 (91.43%)			34 (97.14%)	1 (2.86%)		

Notes:
No PE diagnosed in all patients with CTA performed.
Pre: 7/66 (10%) had positive D-dimer and 6 of them (75%) underwent CTA
Post: 7/27 (21%) had positive D-dimer and 2 of them (2%) underwent CTA

CTA, computed tomographic pulmonary angiography; OR, odds ratio; PE, pulmonary embolism; Pre, pre-intervention; Post, post-intervention; PERC, Pulmonary Embolism Rule-Out Criteria.

Fourth, the overall appropriateness of D-dimer testing and chest CTA was challenging to evaluate because of our retrospective study design. Therefore, we had an incomplete cohort of patients suspected of PE (missing patients who did not have both D-dimer testing and chest CTA) and incomplete testing results (no data of D-dimer testing for patients who underwent chest CTA directly in the low- and intermediate-probability groups). With our limited data, we could only compare the total numbers of D-dimer testings and chest CTAs between the pre- and post-intervention groups. A prospective study would more suitable and recommended in future work.

Lastly, although the ACP suggests best practice guidelines, there is substantial controversy regarding the validity of using an age-adjusted D-dimer.[17] Thus, we chose not to use an age-adjusted D-dimer in this study.

Overall, our intervention was successful in encouraging more judicious use of the chest CTA. Implementation of the diagnostic algorithm and educational intervention also helped reduce testing in a short-term period. However, the long-term impact of the algorithm and intervention is still unknown. Educating providers who are involved in direct patient care with evidence-based medicine is essential and should be routinely applied and reinforced to ensure the effectiveness of long-term practice.

Conflicts of Interest: None

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