Original Article

Use of PERC/Wells in Combination with Other Clinical Prediction Rules to Reduce CTPA Demand in Same Day Emergency Care: A Retrospective Cohort Study

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Abstract

Pulmonary embolism (PE) is a common and potentially life-threatening condition encountered in acute medicine. Clinical prediction rules (CPRs), including PERC, Wells, Revised Geneva, YEARS and LEGEND, have been developed to support rational use of computed tomography pulmonary angiography (CTPA). This study evaluated whether retrospective co-application of Revised Geneva, YEARS or LEGEND alongside an existing PERC/Wells-based diagnostic pathway could reduce CTPA utilisation in a Same Day Emergency Care (SDEC) population.

We conducted a retrospective cohort study of all patients who had CTPA for suspected PE in a UK SDEC unit between January and June 2024. CPRs were applied retrospectively using documented clinical data. The primary outcomes were the potential reduction in CTPA utilisation and the proportion of scans that would have contained PE.

Of 433 CTPAs identified, 362 patients met inclusion criteria. The prevalence of PE among those scanned was 16.6%. Retrospective co-application of Revised Geneva, YEARS and LEGEND would have reduced CTPA utilisation by 5.5%, 29.0% and 39.2% respectively. No PEs were identified among scans potentially avoided using Revised Geneva, whereas PE was present in 4.8% and 5.6% of avoided scans using YEARS and LEGEND. Missed events occurred in a clinically stable ambulatory cohort and were not associated with radiological evidence of right ventricular strain; however, the clinical significance of these findings remains uncertain.

In this selected SDEC population, layering additional CPRs onto an existing diagnostic pathway may have the potential to reduce CTPA utilisation, although strategies achieving larger reductions were associated with missed diagnoses. These findings should be regarded as hypothesis-generating and require prospective validation before informing changes to clinical practice.

Keywords

Pulmonary Embolism, Wells, Revised Geneva, YEARS, Same Day Emergency Care, CT Pulmonary Angiography

Key points

1. **What is already known on this topic:**
   CT pulmonary angiography (CTPA) is frequently used in the investigation of suspected pulmonary embolism (PE), with concerns regarding overuse, radiation exposure and resource burden. Clinical prediction rules such as Revised Geneva, YEARS and LEGEND can safely reduce imaging when used as standalone strategies in unselected emergency department populations, but their role when layered onto existing PE pathways in Same Day Emergency Care (SDEC) is unclear.
2. **What this study adds:**
   In an SDEC cohort already selected for imaging using a PERC/Wells-based pathway, the co-application of additional clinical prediction rules could reduce CTPA utilisation. Revised Geneva provided a small reduction with no missed PEs, while YEARS and LEGEND achieved larger reductions but with a modest proportion of avoided scans containing PE, fewer of which resulted in a change in treatment.
3. **How this study might affect research, practice or policy:**
   These findings provide a pragmatic baseline for future prospective studies evaluating layered diagnostic strategies in SDEC. If validated, such approaches may help reduce unnecessary imaging, improve patient flow and optimise use of hospital resources, though further retrospective, prospective and health-economic evaluation is required before changes to clinical practice are recommended.

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Use of PERC/Wells in Combination with Other Clinical Prediction Rules to Reduce CTPA Demand in Same Day Emergency Care: A Retrospective Cohort Study

Introduction

Pulmonary embolism (PE) remains a leading cause of cardiovascular mortality and a common diagnostic challenge in acute care settings[1]. Its non-specific clinical presentation, encompassing symptoms like dyspnoea, chest pain, and tachycardia, often necessitates objective testing to confirm or exclude the diagnosis[1,2,3]. Computed tomography pulmonary angiography (CTPA) has emerged as the diagnostic cornerstone due to its high sensitivity and specificity[4]. However, its indiscriminate use leads to patient harm, including exposure to ionizing radiation, contrast-induced nephropathy, and anaphylactic reactions, alongside increasing burden on radiology services and associated costs[5].

To address this, validated clinical prediction rules (CPRs) have been developed to estimate pre-test probability and guide rational test utilisation. Wells, the most established tool, incorporates clinical signs and subjective assessment[6]. Revised Geneva offers an alternative that is more objective, focussing instead on clinical signs and symptoms[7]. More recently, YEARS[8] and LEGEND[9] were developed, both of which utilise non-conventional d-dimer cut-offs as part of their assessment.

Wells[10,11], YEARS[12,13] and Revised Geneva[14,15,16] have all undergone separate validation studies. LEGEND has not had separate validation but did have a validation cohort within their initial study[9].

Our current trust protocol in the work up of potential PE in the SDEC setting, involves the use of the Pulmonary Embolism Rule-out Criteria (PERC)[17], followed by Wells to decide whether to proceed to CTPA. This is in line with current NICE Guidance[2,3]. In addition to this, within our department, we utilise the age-adjusted d-dimer, in keeping with the established literature and national guidance[3,18,19,20,21].

The UK's development of the Same Day Emergency Care (SDEC) model[22,23] represents a distinct patient cohort: ambulatory patients who are often complex, with multiple comorbidities, but stable enough to avoid traditional inpatient admission[24]. The performance and safety of these CPRs, particularly in combination, within this specific healthcare delivery model has not been characterised within research.

This study aimed to evaluate whether the co-application of Revised Geneva, YEARS or LEGEND in conjunction with PERC/Wells, could safely reduce the number of CTPA scans performed in a UK SDEC population without compromising the diagnosis of clinically significant PE. This hypothesised study protocol is outlined in Figure 1, which compares this to our current SDEC protocol.

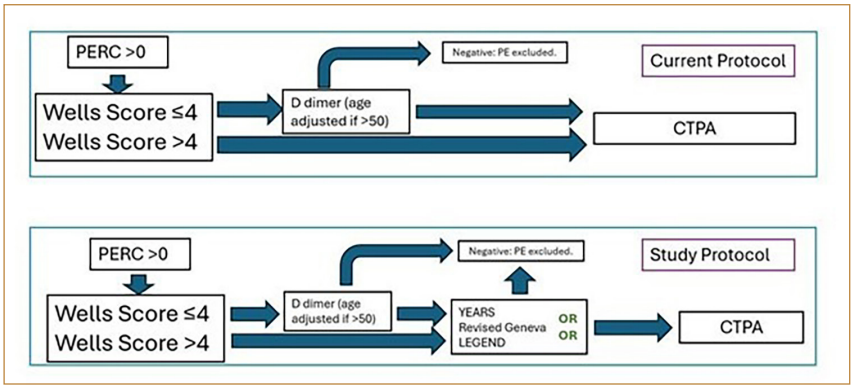

Figure 1. Comparison of Current Protocol with Study Protocol

Methods

Study Design and Setting

This was a retrospective cohort study conducted at the Northumbria Specialist Emergency Care Hospital SDEC unit, a large ambulatory emergency care service in the North East of England. The study received institutional approval in line with NHS data policies. The study population comprised all patients who underwent CTPA for suspected PE between 1st January 2024 and 30th June 2024 in our SDEC unit.

Patient Selection and Exclusion Criteria

Patients were identified from a radiology information system using the procedure code for CTPA. After initial identification, electronic patient records (EPRs) were coded and analysed by members of the research team.

Inclusion criteria were:

1. Age ≥16 years.
2. Patients who attended SDEC and after assessment in line with trust policy had a CTPA requested.

Exclusion criteria were:

1. Known PE on therapeutic anticoagulation at presentation (n=8)
2. Anticoagulation for >24 hours prior to CTPA without a confirmed prior PE (n=24)
3. Pregnancy (n=1)
4. Patients who were not seen by a medical or emergency care doctor prior to their CTPA (n=11)
5. Inadequate CTPA imaging quality for definitive radiological interpretation (n=3)
6. No D-dimer test performed prior to imaging (n=24)

A total of 71 patients were excluded, yielding a final analytical cohort of 362 patients. The first three exclusion criteria align with exclusion criteria from all or some of the original studies for the CPRs being studied[6,7,8,9]. In addition to this, our SDEC has

exclusion criteria for patients on the PE pathway, such as presentation with syncope, heart rate over 110 BPM, systolic BP under 90mmHg, SpO2<92% or respiratory rate over 26. However, these are at the discretion of the accepting consultant at point of referral and exceptions are made on a case-by-case basis.

Data Collection and Variable Definition

Data was extracted from each included patients EPR and collected in a standardised manner into Microsoft Excel to allow each CPR's score to be calculated. Collected variables included:

- **Demographics:** Age, gender (as recorded on EPR).
- **Clinical data:** Vital signs at presentation, symptoms, clinical signs, relevant medical history (cancer, recent surgery/immobility, prior VTE). Relevant medical history was validated by checking the patients GP record where appropriate and available.
- **Investigations:** D-dimer result, CTPA report.
- **Outcome:** The presence of PE on CTPA was the primary outcome. The most proximal anatomical location of PE (lobar, segmental, subsegmental) and CT evidence of right heart strain, if commented on in radiology reports (e.g., RV/LV ratio >1.0, pulmonary artery dilation) were recorded for positive cases. In addition, Pulmonary Embolism Severity Index (PESI) was also calculated[25].

Each record was coded into Microsoft Excel by a doctor with at least two years of postgraduate experience and who currently worked in either acute or respiratory medicine.

Due to the more subjective nature of CPR criterions that utilise clinical gestalt, namely Wells's "PE is the most likely or equally likely diagnosis" and YEARS's "PE is the most likely diagnosis", these were coded by different clinicians. Where there was significant clinician disagreement (i.e coded as not most likely/equally likely in Wells, but most likely in YEARS), this flagged the record for additional senior review and recoding by a consultant in acute medicine (n=44).

Due to the way in which our trust EPR is structured, we were unable to blind coding clinicians to the patient outcome.

Statistical Analysis

Statistical analysis was performed using Microsoft Excel or online calculators for the test in question. The potential reduction in CTPA was calculated by applying the standard algorithms for each CPR and identifying patients who would not be scanned based on the CPR in question:

- Revised Geneva: Those with a score of under 11, with a d-dimer under 0.5ug/ml FEU (or negative age adjusted d dimer).
- YEARS: Patients with 0 YEARS items and a d-dimer under 1.0ug/ml FEU and patients with 1 or more YEARS items, with a d-dimer level under 0.5ug/ml FEU.
- LEGEND: Patients with a LEGEND score under 2.

Patient and Public Involvement

Patients and Public were not involved in the generation of this research question or the methodology of this study.

Results

Demographics & PE Prevalence

A total of 362 patients were included in the analysis. The cohort had a median age of 59 years (IQR 48-72.8) and was predominantly female (n=225, 62.2%), though with no statistical difference in age distribution (p=0.631, t-test). The overall prevalence of PE in those who had CTPA was 16.6% (60/362). PE prevalence was significantly higher (p=0.002, Chi-square) in males that were scanned (36/137, 26.3%) than in females (25/225, 11.1%).

All patients who did not have a d-dimer taken had a Wells score over 4. When comparing PE prevalence between the population in whom Wells was over 4 who had a d-dimer taken versus those who didn't (exclusion criteria 6), there was no significant difference (p=0.951, Chi-square) between groups. The prevalence of PE in the group with a Wells over 4, who had a d-dimer taken was 24.2% (32/132) versus the excluded group with Wells over 4, who did not have d-dimer taken was 25.0% (6/24).

On retrospective scoring, 12 patients had Wells scores that would have suggested that PE could have been excluded without CTPA. None of these patients had PE but have been included in the results below.

Analysis of Potential Missed Pulmonary Emboli

Using the Current Protocol + YEARS strategy, five patients would have had PE present among scans that would not have been performed (IDs 1-5 in Table 2). While this corresponds to 4.8% (n=5) of avoided scans containing PE, only 2.9% (n=3) of avoided scans would have resulted in a change in treatment (IDs 3-5 in Table 2). None of these patients had radiological evidence of right heart strain. One patient had concurrent sepsis, making attribution of physiological compromise to PE difficult. Among the remaining patients, none were hypoxic or hypotensive, and two were anticoagulated for alternative indications (IDs 1 & 2 in Table 2).

Using the Current Protocol + LEGEND strategy, eight patients would have had PE present among scans that would not have been performed (all besides ID 1 in Table 2), corresponding to 5.6% (n=8) of avoided

Table 1. Summary of Diagnostic Performance of Different Protocols

	Current Protocol + Revised Geneva	Current Protocol + YEARS	Current Protocol + LEGEND
Reduction in Scans	5.5%	29.0%	39.2%
Percentage of the reduction in scans that would have changed treatment given (95% CI*)	0% (0-16.1%)	2.86% (1.0-8.3%)	4.9% (2.5-10.3%)
Sensitivity	100%	94.9%	88.3%
Specificity	6.7%	33.7%	44.7%
Positive Predictive Value	17.8%	21.8%	24.1%
Negative Predictive Value	100%	97.1%	95.1%
McNemar's Test	P<0.0001	P<0.0001	P<0.0001

*Calculated via Wilson Confidence Interval.

Statistics quoted in Table 1 are in reference to scans that would have changed the treatment given to the patient.

scans containing PE; however, 4.9% (n=7) of avoided scans would have resulted in a change in treatment (all besides IDs 1&2 in Table 2). Four of these patients overlapped with those identified using YEARS (IDs 2-5 in Table 2). None of the additional patients were hypoxic or hypotensive, nor did they demonstrate radiological evidence of right heart strain.

One patient subsequently diagnosed with antiphospholipid syndrome (APLS) would not have met imaging criteria based on clinical prediction rules alone; however, abnormal coagulation results identified during the SDEC encounter may have prompted further investigation and CTPA irrespective of CPR-based assessment. Inclusion of this patient does not alter the reported number of potentially missed PEs or treatment-changing events for either strategy.

Discussion

Key findings and Interpretation

This retrospective analysis of patients undergoing CT pulmonary angiography (CTPA) within a UK Same Day Emergency Care (SDEC) service suggests that the addition of further clinical prediction rules (CPRs) to an established PERC/Wells-based diagnostic pathway may have the potential to reduce imaging utilisation. The magnitude of this potential reduction varied considerably between the CPRs studied and was accompanied by differing implications for diagnostic safety. To our knowledge, this is the first study to examine the retrospective co-application of multiple CPRs within an existing structured PE pathway in an ambulatory acute care population.

The addition of the Revised Geneva score was associated with a modest reduction in imaging (5.5%) with no PE identified among scans that would potentially have been avoided in this cohort. This finding is consistent with previous literature demonstrating comparable performance between Revised Geneva and Wells, with the advantage of reduced reliance on subjective clinical judgement. In settings such as SDEC, where patients are clinically stable but often diagnostically complex, the use of more objective rule-out strategies may support consistent risk stratification. However, these findings should be interpreted cautiously given the retrospective study design and the selected nature of the study population.

In contrast, co-application of the YEARS and LEGEND algorithms was associated with larger potential reductions in CTPA utilisation but at the expense of missed diagnoses (4.8% with YEARS algorithm, 5.6% with LEGEND score). Although these events occurred within a clinically stable ambulatory cohort and were not associated with radiological features of right ventricular strain, the clinical significance of these pulmonary emboli remains uncertain. When considering treatment change rather than radiological diagnosis, two out of five of the patients for whom YEARS did not identify a PE that was present were anticoagulated for alternative indications during this hospital attendance (DVT and atrial fibrillation), which lowers the proportion of patients for whom the CTPA changed outcome by a reasonable margin.

From a clinical risk perspective, even modest reductions in diagnostic sensitivity may be unacceptable to many clinicians in the investigation of a potentially fatal condition. Accordingly, while these findings provide insight into the efficiency–safety trade-off inherent in diagnostic pathway design, they should not be interpreted as evidence supporting the routine adoption of such combined strategies without prospective validation.

D-dimer thresholds and diagnostic trade-offs

An additional observation from this analysis was that diagnostic strategies incorporating higher D-dimer thresholds were associated with an increased likelihood of missed pulmonary embolism within this selected SDEC cohort. This finding reflects the inherent balance between reducing imaging utilisation and maintaining

Table 2. Potential Missed PEs by not scanning

ID	Age	W	Y	RG	L	DD	Trop	BNP	Other New Diagnosis	PESI	CT Report	CT RHS	Echo RHS	12 Months	Treatment Length	Treatment Change
1	30s	6	2	12	2	0.38	NA	NA	Deep Vein Thrombosis	49	Tiny non-occlusive segmental PE.	No	NA	Alive	3 months	No
2	60s	4.5	0	5	0	0.68	NA	NA	Atrial Fibrillation	101	Right and left lower lobe subsegmental PE.	No	NA	Alive	Lifelong due to AF, but would have been 3 months for PE	No
3	70s	1.5	0	6	0	0.80	NA	NA	Sepsis	111	Very small volume segmental and subsegmental PE.	No	No	Alive	Lifelong	Yes
4	30s	0	0	3	0	0.99	<5	NA	Pneumonia	70	Multiple bilateral segmental PE.	No	NA	Alive	Lifelong	Yes
5	40s	3	0	0	0	0.89	<5	NA		48	Bilateral segmental low volume PE.	No	No	Alive	Lifelong	Yes
6	60s	3	1	3	0	0.67	<5	NA	Anti-phospholipid Syndrome	64	Bilateral lobar, segmental and subsegmental PE.	No	NA	Alive	Lifelong	Yes
7	50s	3	1	3	0	0.80	16	NA		75	Bilateral subsegmental PE.	No	NA	Alive	3 months.	Yes
8	40s	3	1	5	0	0.83	<5	NA	Large Pneumothorax	42	Left segmental PE.	No	NA	Alive	3 months.	Yes
9	50s	4.5	1	5	0	0.55	<5	NA		71	Left segmental and subsegmental PE.	No	NA	Alive	3 months.	Yes

ID: Study ID Number, W: Wells Score, Y: Years Score, RG: Revised Geneva Score, L: Legend Score, Age: Age approximated to decade of life, DD: D dimer (ug/ml FEU), Trop: Troponin (ng/L), BNP: B-type Natriuretic Peptide, Other New Diagnosis: Diagnoses made during visit/admission or from tests done during this, PESI: Pulmonary Embolism Severity Index, CT Report: Summary of the anatomical location of thrombus from CTPA report, CT RHS: Whether the CT report comments that there is right heart strain evident on the scan, Echo RHS: Whether an echocardiogram done during the admission showed right heart strain, 12 months: Whether patient was alive at 12 months or not, Treatment: Length of anticoagulant treatment advised/given to patient for the PE either at initial assessment or subsequent thrombosis clinic, Treatment change: Whether the scan being performed altered the treatment that was given to the patient or not.

diagnostic sensitivity. In SDEC populations, whose risk is stratified by their ambulatory nature, further modification of diagnostic thresholds may have proportionally greater impact on sensitivity than in unselected emergency department cohorts.

From a clinical perspective, the acceptability of any reduction in diagnostic sensitivity in the evaluation of suspected PE remains uncertain and is likely to vary between clinicians and healthcare systems. Although guidance states that treatment with anticoagulants versus watchful waiting in the case of isolated subsegmental emboli is a controversial area with poor evidence[1,26], the emboli identified in this study whilst small in physiological burden, were not isolated events. Therefore, accurate identification of the emboli and initiation of anticoagulant treatment was the correct approach in these patients. Recent guidance[27] has not further clarified whether to anticoagulate isolated subsegmental PE, but does provide more detailed risk stratification of diagnosed PE. Within our cohort, all of the potentially missed PEs fall into AHA/ACC category B (symptomatic, low clinical severity score), with the exception of 2 patients, who fall into category C (symptomatic, elevated clinical severity score). However, these two patients had simultaneous diagnoses that will have

elevated their PESI score (atrial fibrillation and sepsis), making the relative contribution of their PE to their haemodynamic instability difficult to establish.

Study Population, Selection Effects and Pre-test Probability

Revised Geneva, YEARS and LEGEND were originally derived and validated as standalone diagnostic tools intended for use at the point of initial assessment. In this study, however, they were applied retrospectively to a population already selected for imaging based on PERC and Wells criteria. As a result, the pre-test probability of PE in this cohort was inherently higher than in unselected emergency department populations, which likely explains, at least in part, the higher proportion of PEs among scans that would not have been performed using YEARS or LEGEND.

The SDEC model introduces an additional layer of clinical selection by excluding patients with significant haemodynamic instability or severe respiratory compromise, further shaping the risk profile of the study population. Consequently, missed PEs in this study occurred within a clinically stable, ambulatory cohort, limiting the generalisability of these findings to other settings such as resuscitation areas or unselected emergency department populations.

Demographic Considerations

In this cohort, a lower diagnostic yield of CTPA was observed among female patients compared with male patients. This finding is consistent with previously reported sex-based differences in the epidemiology and investigation of suspected pulmonary embolism[28,29]. Several factors have been identified as contributing to this in the literature, including generally higher D-dimer levels in women, higher perceived risk, and the influence of specific elements within existing clinical prediction rules, such as exogenous hormone use criterion, being more frequently positive in female patients[29,30].

Analysis of patients with a Wells score greater than four who did and did not undergo D-dimer testing demonstrated no significant difference in PE prevalence between groups. This supports the internal consistency of the diagnostic pathway within the study population and suggests that higher-risk patients were not systematically excluded by the study design.

Strengths and Limitations:

Our study has several strengths. Firstly, it provides novel, real-world data from a UK SDEC setting, a rapidly growing and previously understudied care model. Secondly, we applied multiple recognised CPRs to the same cohort, allowing for a comparison of their performance when additionally applied to current national guidelines. Finally, our detailed analysis of the location and physiological impact of missed PEs adds crucial clinical context to the raw performance metrics.

The limitations of our study are primarily inherent to its retrospective design. The calculation of scores was dependent on the completeness and accuracy of documentation in the EPR. Variables like "PE is the most likely diagnosis" are subjective and whilst measures were taken to address this, there is still potential for misclassification and hindsight bias. Our clinicians were also not able to be blinded to outcome. The single-centre design limits the generalisability of our findings, as local practices and patient demographics may vary. Furthermore, we lacked formalised follow-up data for patients who had a negative CTPA. It is possible that some patients were subsequently diagnosed with PE at another institution, which would mean our calculated negative predictive values are overestimated.

The reported data in our results section applies to the impact that additional CPRs would have on the requirement for CTPA compared to current practice. Critically, our results do not include patients who had PE excluded based on PERC or Wells, which is likely to be the majority of those for whom PE was considered a differential. Therefore, our failure rates of these combined approaches will be significantly inflated compared to what would be seen if these were applied in clinical practice or in potential prospective studies. Our results are not a commentary on the sensitivity or specificity of Revised Geneva, YEARS or LEGEND when applied to the general population, as by definition we have applied these to a high-risk group; those whom PERC/Wells would suggest should have a CTPA performed.

An ideal study design would have prospectively applied all CPRs at the point of care, with imaging performed for any patient triggering one or more tools, allowing direct comparison of diagnostic performance; however, this was not feasible within the constraints of a retrospective analysis.

Clinical Implications and Future Directions:

The findings of this study highlight the importance of evaluating diagnostic strategies for suspected pulmonary embolism within the specific context of Same Day Emergency Care (SDEC), which represents a clinically distinct and increasingly utilised care model. While the retrospective modelling performed in this analysis suggests that combining additional clinical prediction rules with existing pathways may influence imaging utilisation, these observations should be regarded as exploratory.

Given the trade-off observed between reductions in CTPA utilisation and diagnostic sensitivity, any modification to established diagnostic pathways would require careful prospective evaluation. Future

studies should aim to assess the real-time application of combined clinical prediction strategies within SDEC populations, incorporating structured follow-up to detect delayed or missed diagnoses and evaluating patient-centred outcomes, clinician decision-making, and health-economic impact.

Such work would help determine whether tailored diagnostic approaches can optimise resource use while maintaining patient safety. Until prospective validation is available, the results of this study should not be interpreted as supporting changes to current clinical practice but rather as providing a framework for the design of future research.

Conclusion

In this retrospective single-centre SDEC cohort, the additional application of selected clinical prediction rules to an established PERC/Wells-based diagnostic pathway was associated with varying potential reductions in CTPA utilisation. The addition of the Revised Geneva score demonstrated a modest reduction in imaging without missed pulmonary embolism in this sample, whereas strategies incorporating YEARS or LEGEND were associated with larger reductions but with missed diagnoses.

These findings illustrate the balance between diagnostic efficiency and sensitivity when modifying investigation pathways for suspected pulmonary embolism in clinically selected ambulatory populations. However, given the retrospective design and the uncertainty regarding the clinical significance of missed events, the results should be considered hypothesis-generating. Prospective studies are required to determine whether such approaches can safely optimise imaging utilisation without adversely affecting patient outcomes. Accordingly, the present data should not be used to alter current clinical practice, but they provide a pragmatic basis for prospective evaluation of layered diagnostic strategies in SDEC.

Conflicts of Interest

The authors declare no conflicts of interest relevant to this manuscript.

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