APPLYING HUMAN FACTORS TO CDS

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WHAT IS A CDS?

OVERVIEW

Diagnostics

- Errors can result in safety issues
- CDS often not used by physicians
- Morbidity vs. Overtesting
- CDS as a support according to established pathways for pulmonary embolism (PERC) & Well's Scoring.

Improved Diagnosis

- Automation to increase usability
- HF design principle & usability Heurstics
- Reduction of Error

Current Limitations

- Not much current research on HF principles applied to CDS
- Most research is geared toward medication safety, preventive care, clinical reminders

Wells' Criteria for Pulmonary Embolism

Objectifies risk of pulmonary embolism.

When to Use | Pearls/Pitfalls | Why Use

Clinical signs and symptoms of DVT	**No 0**	Yes +3
PE is #1 diagnosis OR equally likely	**No 0**	Yes +3
Heart rate > 100	**No 0**	Yes +1.5
Immobilization at least 3 days OR surgery in the previous 4 weeks	**No 0**	Yes +1.5
Previous, objectively diagnosed PE or DVT	**No 0**	Yes +1.5
Hemoptysis	**No 0**	Yes +1
Malignancy w/ treatment within 6 months or palliative	**No 0**	Yes +1

0.0 points

Low risk group: 1.3% chance of PE in an ED population.

Another study assigned scores ≤ 4 as "PE Unlikely" and had a 3% incidence of PE.

Copy Results | Next Steps

OBJECTIVES & HYPOTHESES

- Hypothesis 1 (effectiveness). Because PE-Dx provided cognitive support for the diagnostic clinical pathway, it would be more likely to lead to appropriate decision regarding diagnostic pathway, and greater confidence in decision as compared with the web-based CDS.
- Hypothesis 2 (efficiency). Because the PE-Dx was designed according to HF principles (eg, automation and workload minimisation), it would be more efficient and would lead to faster performance, fewer clicks and scrolls, and lower perception of workload as compared with the web-based CDS.
- Hypothesis 3 (satisfaction). Because the design of the PE-Dx CDS incorporated HF methods and principles, it would be more satisfying and produce a more positive score of perceived usability as compared with the web-based CDS.

- Development of PE-Dx CDS
- Improvement of diagnostic decision making & usability using HF principles
- PE-Dx CDS vs web-bases CDS

METHODS & PROCEDURES

Organizational Setting

The study was conducted at a teaching hospital's emergency department (ED) that had been using an EHR system for several years.

Development of PE-Dx CDS

- Diagnostic pathway using Wells' Score & PERC rule
- PE-Dx was integrated into existing HER system
- Autopopulation

Study Design & Procedures

- Repeated measures scenario study
- 2018 10 week study with 24 ED residents
- Study conducted in HER test environment with presented scenarios & asked to complete tasks
- Survey completed after session 2 evaluating MDCalc or PE-Dx

Data Collection, Measurement, & Analysis

- Screen Captures (Camtasia)
- Stopwatch
- Surveys
- Bayesian regression model

DESIGN OF PE-DX CDS

Table 1 HF design of PE-Dx CDS

HF design process	Design activities and outcomes
1. HF analysis of PE diagnosis in the ED	Identification of multiple work system barriers and facilitators to cognitive work involved in PE diagnosis; in particular technology-related barriers for information gathering activities in PE diagnostic process
2. Analysis of suggestions made by ED physicians regarding health IT solutions	Main suggestions for CDS to support PE diagnosis in ED included: ► Integration with EHR ► Auto-population ► Automated scoring ► Support for decision regarding order.
3. Nine interdisciplinary design sessions over 1 year for a total of 13.5 hours (each session was between 1 and 2 hours)	Decision by design team to focus the CDS on how to support diagnostic pathway for PE diagnosis. Multiple disciplines involved in design sessions: HF, emergency medicine and software engineering/programming. Use of iterative design process with multiple mock-ups of PE-Dx CDS (created in PowerPoint)
4.Two 1-hour focus groups with four ED physicians (interspersed between design sessions) for review of PE-Dx CDS mock-up	Confirmation of preference for two-step CDS: presentation of Wells' and then PERC; match with hospital policy. Use of highest heart rate/pulse value and lowest O_2 saturation value; but need to allow physicians to update these values
5.Creation of PE-Dx CDS in EHR Playground	Programming of PE-Dx CDS in EHR Playground based on PowerPoint mock-up
6.Two-hour participatory heuristic evaluation of PE-Dx CDS with seven participants (HF engineers, physicians, systems analyst)	Identification of 19 usability problems; 13 problems resolved through design changes to PE-Dx CDS; six problems not addressed because of constraints of flowsheet functionality of local EHR Production of final PE-Dx CDS tested in usability evaluation

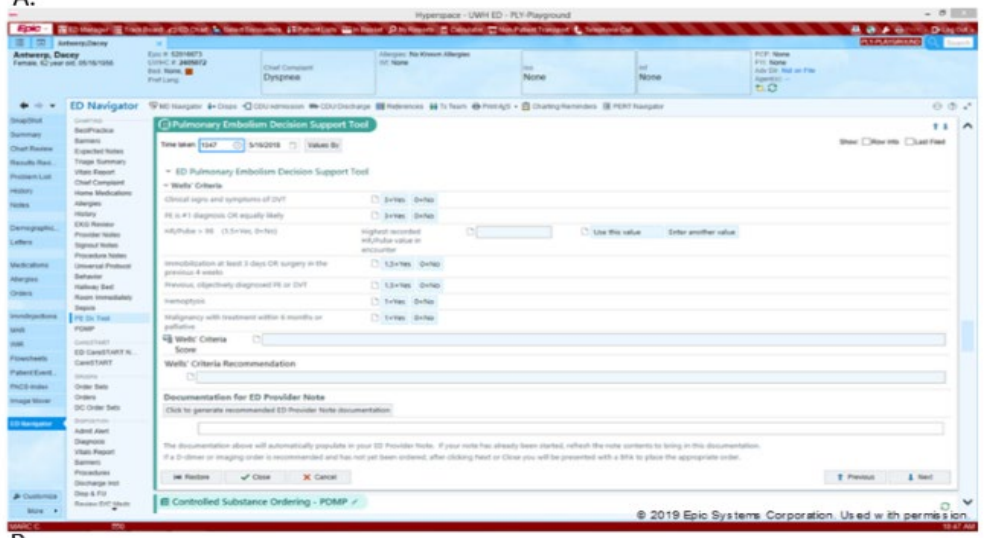
ED, emergency department; IT, information technology; PE-Dx CDS, clinical decision support for pulmonary embolism diagnosis.

HF design principles	Implementation in PE-Dx CDS
Automation of information acquisition[35]	Auto-population of some Wells' and PERC criteria using EHR data
Automation of information analysis[35]	Computation of Wells' score by CDS
Support of decision selection[35]	Provision of recommendation for next step in diagnostic pathway, for example, doing nothing, ordering D-dimer, ordering CTA scan
Explicit control/flexibility[35 36]	Ability to change values for Wells' criteria—for example, possible to change heart rate/pulse—to support physician clinical judgement and unique patient situations
Minimisation of workload[36]	Minimisation of data entry; for example, data for Wells' automatically populated in PERC PERC appears only if Wells' score is low No need to enter data for all PERC criteria once any PERC criterion is positive Automatic generation of text for documentation of medical decision-making
Consistency[36 37]	Consistency with how information is presented in other parts of the EHR; for example, use of Yes/No toggle Consistency with how Wells' and PERC criteria are listed on MDCalc website that is routinely used by physicians
Chunking/grouping[36 74]	Wells' criteria and PERC rule presented separately Placement of CDS in ED navigator of EHR
Visibility[37]	Indication of points/weights assigned to each Wells' criterion to make it clear/transparent how Wells' score is computed
Error prevention[36 37]	To avoid documenting wrong Wells' score, all Wells' criteria must be addressed

HF, human factors; PERC, pulmonary embolism rule-out criteria.

DESIGN OF PE-DX CDS

A.



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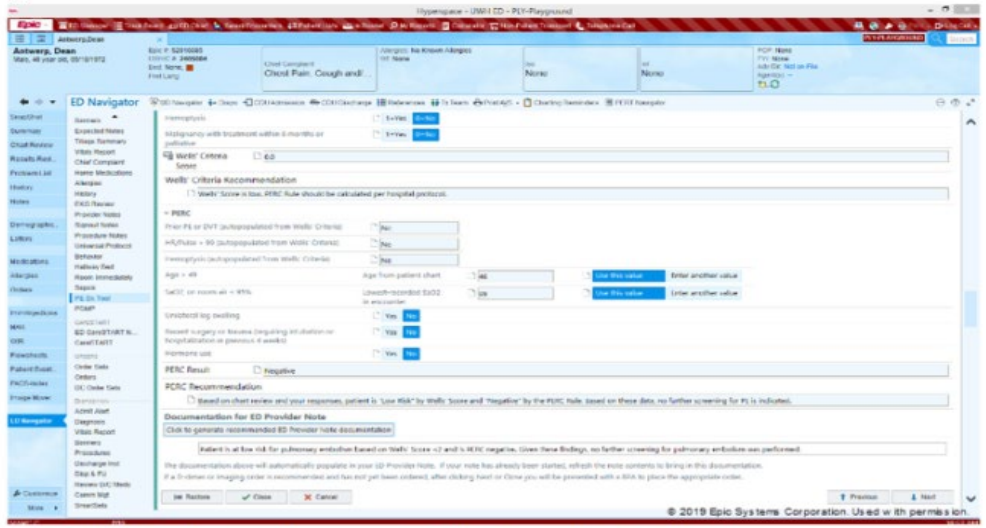

Figure 1 PE-Dx CDS: wells' criteria, wells' score and recommendation (A); PERC criteria (B). PE-Dx CDS, clinical decision support for pulmonary embolism diagnosis; PERC, pulmonary embolism rule-out criteria.

Table 2 Comparison of diagnostic decision pathway with MDCalc and PE-Dx CDS

	MDCalc (web-based CDS)	PE-Dx CDS
Integration with EHR		
	Not integrated in EHR; separate website	Integrated in EHR
Wells' score (seven criteria)		
Initiation	User needs to open browser, type MDCalc PE in search engine in browser and click on URL for MDCalc website	User clicks on PE-Dx button in ED Navigator
Criteria responses	User does not have to answer all (7) criteria before obtaining a score	User has to address all (7) criteria before obtaining the Wells' score
Auto-population	No criteria are auto-populated; therefore, the user may need to navigate between the EHR and MDCalc to search for relevant information	One criterion (heart rate >100) is auto-populated; user may need to navigate within the EHR to search for other relevant information
PERC rule (eight criteria)		
Initiation	User must access a different website within MDCalc to review PERC criteria	PERC is integrated in CDS and becomes active when indicated per hospital policy
Criteria responses	User must respond yes to only one criterion to receive PERC-positive result	User must respond yes to only one criterion to receive PERC-positive result
Auto-population	Does not auto-populate, nor copy results from Wells' criteria. Therefore, user may need to navigate between the EHR and MDCalc to search for relevant information	Auto-populates three questions (age, heart rate, O_2 saturation) and copies forward responses from comparable Wells' criteria (prior PE or deep vein thrombosis, hemoptysis). Therefore, user must address only three criteria (recent trauma or surgery, exogenous oestrogen, unilateral leg swelling)
Risk assessment and decision-making		
Result/score	Provides the user with a score (eg, 3.0 points for Wells' score) and compares that score with the population (eg, moderate-risk group: 16.2% chance of PE in ED population)	Provides the user with a score
Recommendations/next steps	Provides the user with suggestion for next steps; suggestion uses two different models, which can be confusing	Provides the user with a single recommendation in accord with hospital policy and established guidelines[49]
Order *	Does not automatically provide option to enter an order	Provides the option to go to CPOE to order D-dimer or CTA scan when applicable
Documentation *	Allows user to copy results (summary and scores on individual questions) into an EHR note, but user must register to use the feature	Allows the user to populate the results and recommendation directly into his/her note

*The automated creation of an order and documentation of the decision were not tested in this study, but are available in the implemented version of PE-Dx CDS.

CPOE, computerized provider order entry; CTA, CT angiography; ED, emergency department; PE, pulmonary embolism; PE-Dx CDS, clinical decision support for pulmonary embolism diagnosis; PERC, pulmonary embolism rule-out criteria.

RESULTS

88%

Between 25 – 34 years old

100%

Retention

94%

Effectiveness with high confidence

96S

Efficiency

88%

Satisfaction

Table 3 Impact of PE-Dx CDS on usability (mean score (standard deviation), effect size (95% CI) and p value) (n=32)

Dependent variables	MDCalc	PE-Dx CDS	Effect size (CI)	P value
Effectiveness				
% appropriate decision	83.75% (134/160)	94.38% (151/160)	0.35* (0.32 to 0.37)	p<0.01
Confidence level†	80.21 (18.94)	82.71 (18.21)	0.13‡ (–0.05 to 0.31)	p=0.14
Efficiency				
Time per scenario (in seconds)	117.37 (38.91)	95.84 (25.42)	–0.55‡ (–0.71 to –0.38)	p<0.001
Number of clicks per scenario	16.49 (4.82)	17.90 (3.91)	0.29‡ (0.09 to 0.48)	p<0.01
Number of scrolls per scenario	7.47 (2.92)	6.31 (2.50)	–0.39‡ (–0.57 to –0.21)	p<0.001
Number of navigation elements per scenario	15.53 (5.01)	10.23 (2.74)	–1.05‡ (–1.26 to –0.83)	p<0.001
Perceived workload¶	4.45 (1.53)	3.64 (1.78)	–0.52‡ (–0.68 to –0.37)	p<0.001
Satisfaction§				
CUSQ: overall satisfaction	5.62 (0.94)	6.18 (0.66)	0.58‡ (0.18 to 0.98)	p<0.001
CUSQ: system usefulness	5.65 (0.95)	6.26 (0.67)	0.62‡ (0.19 to 1.05)	p<0.01
CUSQ: information quality	5.73 (0.98)	6.17 (0.73)	0.43‡ (0.03 to 0.83)	p<0.05
CUSQ: interface quality	5.48 (1.15)	6.02 (0.86)	0.45‡ (0.07 to 0.84)	p<0.05

*Cohen (h) effect size based on the inverse sine of the square root of the proportional values.
†One question: 0 (no confidence) to 100 (very high confidence).
‡Becker[75] adjusted effect size for repeated measures.
§Response categories: 1 (strongly disagree) to 7 (strongly agree).[55]
¶Scale: 1 (low) to 10 (high).[54]
CUSQ, computer system usability questionnaire; PE-Dx CDS, clinical decision support for pulmonary embolism diagnosis.

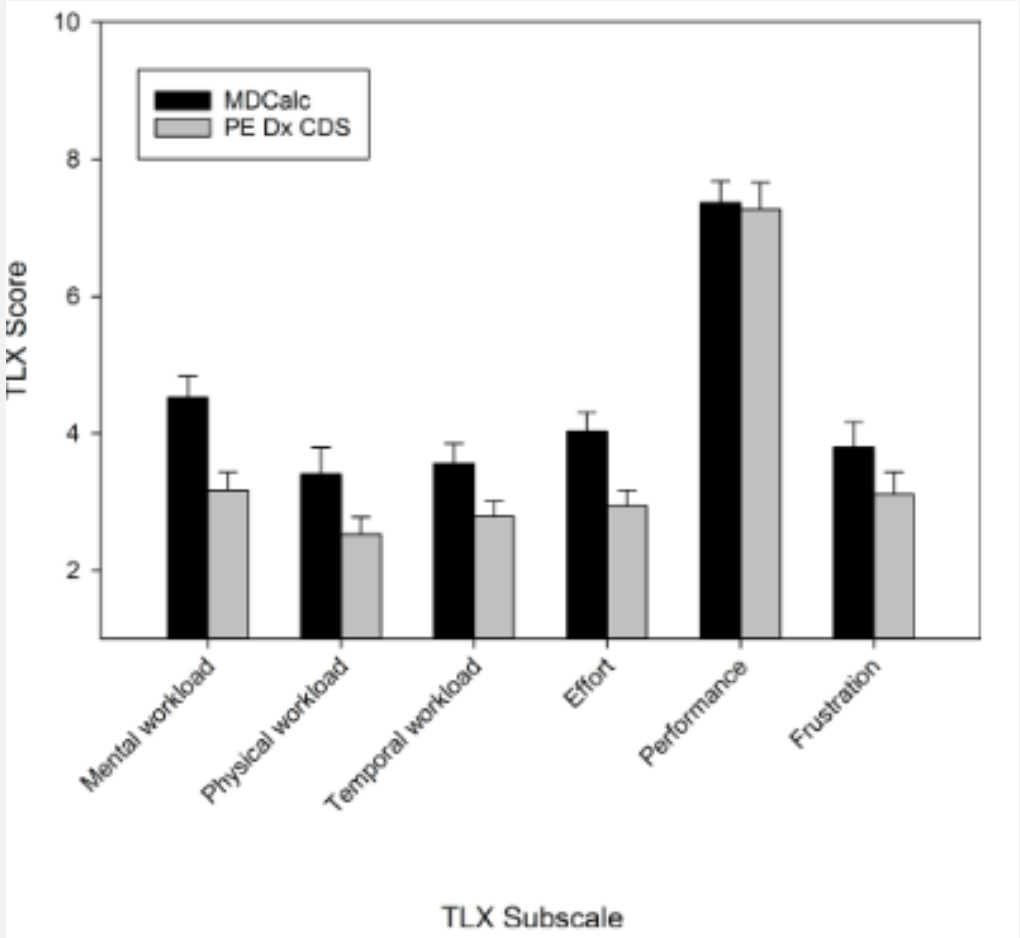

Figure 2 Impact of PE-Dx CDS on perceived workload. Results are shown as mean±SEM. Higher scores indicate higher perceived workload. The differences on the NASA-TLX subscales were statistically significant, except for performance. PE-Dx CDS, clinical decision support for pulmonary embolism diagnosis.

DISCUSSION

Importance of HF-based CDS design

- Improved Usability
- Workflow pathway
- Role of automation
- Decreased workload

Implications for Safety & Outcomes

- Cognitive Support
- Stress Reduction
- Increased usability with physician collaboration

Future Research Suggestion for CDS Designs

- AI enhancement for CDS design
- Effectiveness in clinical settings
- Further automated functions
- Research with other ED physicians at other hospitals

CONCLUSION

- HF principles are beneficial to improving CDS technology
- Automation, information analysis, & decreasing workload are critical to improvement
- Future research can further explore the effects in additional clinical settings, AI enhancement, & automation

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