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ORIGINAL RESEARCH

Gaps in the Care of Pulmonary Hypertension: A Cross-Sectional Patient Simulation Study Among Practicing Cardiologists and Pulmonologists

Enrico de Belen, MD; John W. McConnell, MD; Jean M. Elwing, MD; David Paculdo, MPH; Ian Cabaluna, MD; Jörg Linder, PhD; John W. Peabody, MD, PhD

BACKGROUND: Diagnosis of pulmonary hypertension (PH) is often delayed or missed, leading to disease progression and missed treatment opportunities. In this study, we measured variation in care provided by board-certified cardiologists and pulmonologists in simulated patients with potentially undiagnosed PH.

METHODS AND RESULTS: In a cross-sectional study (https://www.clinicaltrials.gov, NCT04693793), 219 US practicing cardiologists and pulmonologists cared for simulated patients presenting with symptoms of chronic dyspnea and associated signs of potential PH. We scored the clinical quality-of-care decisions made in a clinical encounter against predetermined evidence-based criteria. Overall, quality-of-care scores ranged from 18% to 74%, averaging 43.2%±11.5%. PH, when present, was correctly suspected 49.1% of the time. Conversely, physicians incorrectly identified PH in 53.7% of non-PH cases. Physicians ordered 2-dimensional echocardiography in just 64.3% of cases overall. Physicians who ordered 2-dimensional echocardiography in the PH cases were significantly more likely to get the presumptive diagnosis (61.9% versus 30.7%; $P<0.001$). Ordering other diagnostic work-up items showed similar results for ventilation/perfusion scan (81.5% versus 51.4%; $P=0.005$) and high-resolution computed tomography (60.4% versus 43.2%; $P=0.001$). Physicians who correctly identified PH were significantly more likely to order confirmatory right heart catheterization or refer to PH center (67.3% versus 15.8%; $P<0.001$).

CONCLUSIONS: A wide range of care in the clinical practice among simulated patients presenting with possible PH was found, specifically in the evaluation and plan for definitive diagnosis of patients with PH. The delay or misdiagnosis of PH is likely attributed to a low clinical suspicion, nonspecific symptoms, and underuse of key diagnostic tests.

REGISTRATION: URL: https://www.clinicaltrials.gov; Unique identifier: NCT04693793.

Key Words: cardiology ■ clinical practice ■ practice variation ■ pulmonary hypertension ■ pulmonology

Pulmonary hypertension (PH) encompasses multiple clinical conditions that are chronic, progressive, and often lead to disability and mortality. These conditions are classified into 5 groups of diseases, with 2 of the most important treatable causes of PH being pulmonary arterial hypertension (PAH) and chronic thromboembolic PH (CTEPH). Overall, the most common causes of PH are left heart disease (LHD; eg, congestive heart failure [CHF]) and lung disease (eg, chronic obstructive pulmonary disease [COPD]).[1]

A significant number of patients with PH and their doctors do not know they have the disease, often embarking on wasteful diagnostic odysseys, which results in a delay or even an incorrect diagnosis.[2] Delayed and missed diagnosis, in turn, means that patients miss out on evidence-based treatment, including medications

Correspondence to: John W. Peabody, MD, PhD, QURE Healthcare, 450 Pacific Ave, Suite 200, San Francisco, CA 94133. Email: jpeabody@qurehealthcare.com

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CLINICAL PERSPECTIVE

What Is New?

- Using online, simulated patients, we conducted a study measuring the clinical decision making of a nationwide sample of cardiologists and pulmonologists.
- Study participants were asked to care for patients presenting with chronic dyspnea and determine their patient's diagnosis and treatment plan.
- Despite these simulated patients presenting with chronic dyspnea, physicians only considered pulmonary hypertension in their diagnosis about half the time.

What Are the Clinical Implications?

- This study shows that the diagnosis of pulmonary hypertension is often delayed or missed, leading to advanced disease progress and poorer outcomes.
- An opportunity exists to improve the quality of care of patients with pulmonary hypertension.

Nonstandard Abbreviations and Acronyms

CPV	Clinical Performance and Value
CTEPH	chronic thromboembolic pulmonary hypertension
HRCT	high-resolution computed tomography scan
IPAH	idiopathic pulmonary arterial hypertension
LHD	left heart disease
PAH	pulmonary arterial hypertension
PH	pulmonary hypertension
QR-BADGE	QURE Randomized Controlled Trial to Evaluate Biomarker Assessment of Dyspnea to Guide Disease Evaluation
RHC	right heart catheterization

and surgery that have the potential to improve patient outcomes. To avoid the protracted patient diagnostic journey, physicians must suspect and work-up unexplained chronic dyspnea, doing blood tests, imaging studies, and ultimately right heart catheterization (RHC).[1,3]

If we better understand how patients with PH are evaluated, we would be able to understand why the diagnosis is delayed or missed. Previous studies, by construct, have only been able to look retrospectively at the problem of misdiagnosis and late diagnosis after the patient with PH has been identified. This limits our understanding of PH in 2 ways. Unless a diagnosis of PH is made, it is impossible to understand why those patients were misdiagnosed. Similarly, after they were diagnosed, we are only understanding how patients with PH are evaluated in a static retrospective fashion rather than dynamically as they go through the work-up and evaluation.[2,4,5] A better, more useful approach would be to evaluate how patients in earlier stages who present with chronic dyspnea but who have not been diagnosed are evaluated.

In the past decade, researchers trying to understand clinical practice variation have turned to simulated patients to understand gaps in clinical care.[6,7] The advantage of a simulated patient is that it focuses on the process of care provided in clinical practice and eliminates patient-level variation.[8] Clinical Performance and Value (CPV) vignettes are a validated method to simulate and measure actual clinical practice and allow us to focus on physician practice variability by having every physician take care of the same set of patients, thereby eliminating patient heterogeneity.[8,9]

The QURE Randomized Controlled Trial to Evaluate Biomarker Assessment of Dyspnea to Guide Disease Evaluation, known as the QR-BADGE study, looked at the clinical practice patterns related to the clinical care provided by cardiologists and pulmonologists taking care of undiagnosed patients with typical presentations of PH. The goal of this study is to identify opportunities to improve the recognition and diagnosis of PH. Herein, we examined the baseline clinical practice of specialists to measure the diagnosis and treatment patterns for patients presenting with symptoms highly suspicious of PH and to determine whether care remains widely varied despite having clearly directed PH guidelines.

METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable request. The QR-BADGE study was conducted between March and July 2021. Using simulated patients, we measured and analyzed data on clinical practice variation focusing on the work-up, diagnosis, and management of PH.

Ethics

The study was conducted in accordance with ethical standards, approved by Advarra Institutional Review Board, Columbia, MD, and listed in https://www.clinicaltrials.gov (NCT04693793). Informed consent was obtained from all physicians through an online voluntary consent process. All data were kept confidential.

Physician Selection

From a national roster of >15 000 practicing cardiologists and pulmonologists, we contacted ≈1500 pulmonologists and cardiologists each to participate in the study via an email campaign. We used a 17-item questionnaire with included questions on the following eligibility criteria: (1) were board-certified in cardiology or pulmonology for at least 2 years, (2) averaged at least 20 hours per week of clinical and patient care duties during the past 6 months, (3) reported they routinely evaluated patients for unexplained or chronic dyspnea in their practice, (4) practiced in the United States, (5) were English speaking, (6) had access to the internet, and (7) voluntarily gave informed consent to participate in the study. A total of 354 specialist physicians completed the self-administered questionnaire; 249 were deemed eligible and agreed to participate in the study. A total of 21 physicians subsequently either retracted their consent to participate (n=3) or never responded when the study was launched (n=18). Of the physician specialists, 9 began but did not complete their participation and were subsequently dropped. The final study population consisted of 219 physician specialists (106 cardiologists and 113 pulmonologists) who completed the study. No significant difference in the baseline characteristics of the 30 incomplete participants compared with the 219 who completed the study (P>0.05 for all) was observed. The participants were offered and paid fair market value for their time participating in the study.

Data Sources

Physician Survey

Once enrolled, the cardiologists and pulmonologists were given a 13-item questionnaire asking them to detail their practice and professional background. This survey included questions on employment status, location of practice, inpatient versus outpatient care, and practice type, among others.

CPV Cases

To collect data on clinical practice variation, we used CPV vignettes. The CPV vignette is a validated online patient simulation tool now widely used to measure clinical care.[10,11] The vignettes are open-ended questions and are divided into the following 5 domains of care: (1) taking a history, (2) performing a physical exam, (3) ordering diagnostic work-up, (4) making a diagnosis, and (5) formulating a treatment plan with follow-up. CPVs have also been used to evaluate and compare clinical practice of health care physicians in a comprehensive range of clinical conditions and settings.[6,12–14]

CPVs have physicians care for the simulated patients just as they would in their clinic setting and provide further patient data as the care progresses. (See Figure S1 for a sample case walkthrough.) Additional details of the CPV methodology are available.[15,16]

In QR-BADGE, there are between 61 and 74 evidence-based criteria in each CPV based on relevant clinical guidelines, best practice, and the published literature. A total of 2 trained expert physicians, working independently and blinded to participant identities, evaluate the clinical care provided. A third physician serves as an adjudicator in case of any disagreement in scoring the individual criteria. A quality-of-care score, ranging from 0% to 100%—based on how many of the evidence-based criteria the physician correctly makes divided by the total number of evidence-based criteria available—is then generated in each specific clinical domain of care (history, physical exam, diagnostic work-up order, diagnosis, and treatment plan development and outline), and a combined overall quality-of-care score is then calculated.[17]

PH Cases

We created 9 CPV cases to be cared for by the participating physicians selecting specific diagnoses based on potential impact and burden of PH: (1) idiopathic pulmonary arterial hypertension (IPAH), (2) CTEPH, and (3) PH from LHD/CHF or from lung disease. These 3 case types each had 3 variants: an obvious PH presentation, a more subtle PH presentation, and a chronic dyspnea presentation that did not have PH. All cases resemble a typical patient presenting as possible PH. The physicians were asked to care for 3 randomized, simulated CPV patients, 1 from each case type. The cases are summarized in Table S1.

Analysis

The primary outcomes were to measure the current practices in the work-up, diagnosis, and follow-up care of patients suspected of having PH. Specifically, we aimed to (1) determine the frequency the 2 groups of specialists are able to identify and provide the most suitable follow-up evaluation for patients suspected of having PH and (2) determine how often specific clinical practices (eg, ordering 2-dimensional [2D] echo, ventilation/perfusion scan, high-resolution computed tomography scan (HRCT), and BNP [B-type natriuretic peptide]) test help the diagnosis journey and refer for a definitive diagnosis in 1 of 3 causes: IPAH (PH group 1), CTEPH (PH group 4), and PH associated with LHD/CHF or lung disease (PH groups 2 and 3, respectively).[1]

Summary statistics were determined for all variables. Numerical variables were summarized through mean and SD or median and interquartile range. We used χ^2 tests and logistic regression modeling for analyses involving binary outcome variables (eg, diagnosing PH), and t tests and linear regression modeling

were used for the analysis of continuous outcomes (eg, diagnosis treatment scores). All analyses were performed using Stata 15.1.

RESULTS

Physician Characteristics

A total of 219 board-certified pulmonologists and cardiologists met the eligibility requirements and completed the physician questionnaire and the 3 CPV patient cases (Table 1). The sample was evenly split between board-certified cardiologists (48.4%) and board-certified pulmonologists (51.6%). In line with national averages for the United States, men made up 81.4% of the participants, and the mean±SD age was 52.5±10.5 years. The physician participants had on average 23.8±11.0 years of practice experience, and most worked in an urban or suburban setting (93.9%). By practice type, nearly 85% worked in either an academic setting (43.3%) or in private practice (40.5%), with the remainder (16.3%) working in community hospitals. Most of our study participants (89.3%) were employed by their practice, and nearly half (46.5%) received a quality bonus, providing 50 hours per week of patient care, almost three-fifths (58.7%) of which are in the outpatient setting. The average payer mix for these specialists was 38.3% commercial, 54.1% Medicare/Medicaid, 4.1% self-pay, and 3.5% other forms of payment.

Variability of Physician Practice

The 219 physicians cared for 3 randomized CPV patients, 1 from each case type and variant. A total of 657 simulated patient cases were completed. We compared each physician's ability to evaluate their patients against explicit, evidence-based criteria.

A wide variation in overall care for patients being worked up for PH was found. The overall quality-of-care scores across all cases ranged from 18% to 74% (Figure), with an average score of 43.2%±11.5% (Table 2). To investigate further, we drilled down into the domains of care and found that the variation extended from the work-up (range, 0%–75%), to diagnosis (range, 0%–100%), and definitive evaluation (range, 0%–80%).

The variation was high regardless of case type. Albeit worryingly low, physicians did slightly better on the IPAH cases, scoring 46.1%±11.7%, followed by the PH associated with LHD/CHF or lung disease cases (43.1%±10.6%) and CTEPH cases (41.0%±10.9%) (P<0.001). In a multivariate regression model, controlling for physician characteristics and case types, 3 significant predictors of quality of care were found: age ≤45 years, +3.9% (P=0.001); practitioners in the Northeast, +2.5% (P=0.008); and pulmonologists, +4.7% (P<0.001). Much of the improvement seen in the pulmonologists' scores was driven by more careful history taking (eg, asking about duration and severity of chief complaint; past medical, social, and family history; and current medications) (+4.0%; P<0.001) and physical examination (+9.2%; P<0.001).

Table 1. Baseline Physician Characteristics

Variable	Value*
Sex	
Male	81.4
Female	18.1
Prefer not to say/other	0.5
Average age, y (mean±SD)	52.5±10.5
Specialty	
Cardiology	48.4
Pulmonology	51.6
Experience, y (mean±SD)	23.8±11.0
Hours per week providing patient care (mean±SD)	49.9±14.7
Time in outpatient setting, % (mean±SD)	58.7±24.7
Region	
Northeast	32.9
South	29.1
Midwest	22.1
West	16.0
Practice type	
Academic	43.3
Community hospital	16.3
Private, multispecialty	14.0
Private, single specialty	22.8
Private, solo	3.7
Practice setting	
Urban	56.7
Suburban	37.2
Rural	6.1
Employed by practice	89.3
Participate in CMS Advanced Payment Model	
Yes	34.4
No	30.2
Do not know	35.4
Receive bonus meeting quality targets	46.5
Payer mix	
Commercial	38.3
Medicare	38.0
Medicaid	16.1
Self	4.1
Other	3.5

CMS indicates Centers for Medicare & Medicaid Services.
*All values are percentages except as noted.

Diagnostic Accuracy

To further understand the dynamic process of evaluating patients being worked up for PH, an overall

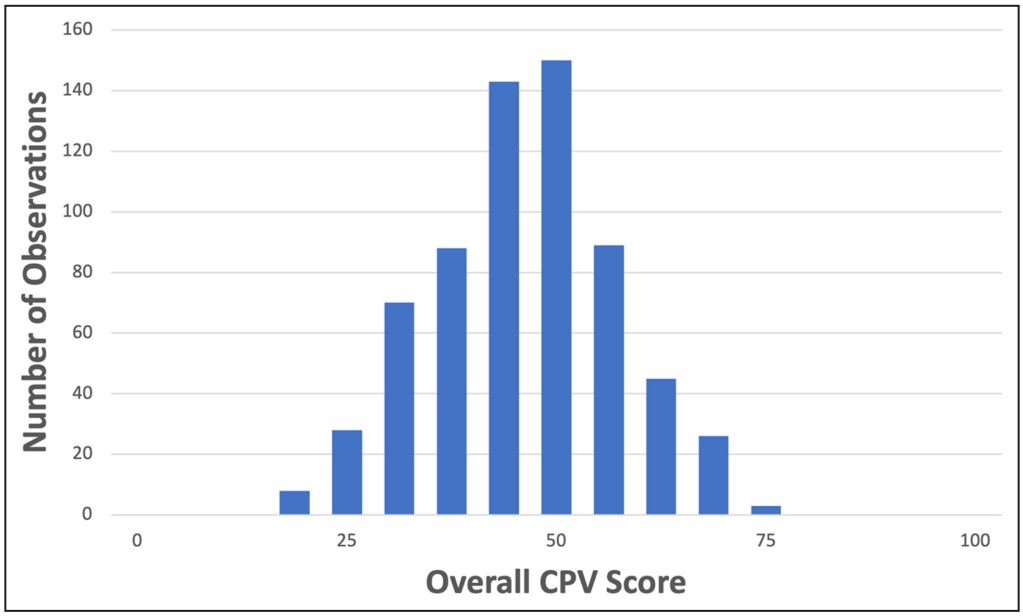

Figure. Distribution of overall CPV scores by percentage (higher score indicates greater adherence to evidence-based and clinical guidelines).
CPV indicates Clinical Performance and Value.

diagnostic accuracy score for the 3 case types was calculated. This score measures the accuracy of making a preliminary diagnosis of PH plus identifying the comorbidities and specifying the risk factors for the patient. The average diagnostic accuracy score for the 3 cases was 46.1%±36.3%, with significant differences between case types (54.4%±38.3% for IPAH, 39.0%±34.9% for CTEPH, and 45.8%±33.4% for PH-LHD/CHF or PH-lung disease; $P<0.001$). When focusing on the accuracy of making the preliminary primary diagnosis of PH, physicians diagnosed PH 49.1% of the time when it was present. When PH diagnosis was missed, the most common misdiagnoses were COPD/restrictive lung disease in the IPAH cases, pulmonary embolism in the CTEPH cases, COPD in the PH-lung disease case, and heart failure with preserved ejection fraction in the PH-LHD case.

Conversely, when a patient presented with symptoms consistent with PH but who, after being worked up, did not turn out to have PH (ie, interstitial lung disease, chronic liver disease, and COPD), physicians were more able to make a non-PH primary diagnosis in the non-PH cases versus a PH diagnosis in the PH cases (63.1% versus 49.1%; $P=0.001$). However, even in the non-PH cases, PH was incorrectly suspected as part of the physicians' differential diagnosis in 53.7% of these cases, regardless of whether they ultimately got the correct diagnosis. By specialty, pulmonologists were significantly more likely to make a PH diagnosis in the PH cases (55.2% versus 42.2%; $P=0.007$) but were as likely as cardiologists to make an incorrect diagnosis of PH in the non-PH cases (55.4% versus 51.9%; $P=0.608$).

A multivariate regression analysis showed that a careful physical examination improved the diagnostic work-up score: for every 5 percentage points' increase in physical examination, physicians scored 1 percentage point higher in the work-up ($P<0.001$). Although a more careful physical exam (odds ratio [OR], 1.04 [95% CI, 0.99–1.10]) did not lead to significant improvements for making the presumptive PH diagnosis, a higher diagnostic work-up score significantly increased the ability to make the correct preliminary diagnosis: each 5-percentage point improvement in work-up led to a significant increase in correctly identifying the primary diagnosis (OR, 1.32 per 5 percentage points' increase [95% CI, 1.22–1.44]). Similarly, a correct preliminary primary diagnosis was 3.0 times more likely to predict doing an RHC or referral (OR, 3.03 [95% CI, 2.36–3.89]). Improved diagnostic testing (OR, 1.17 [95% CI, 1.07–1.28]) was the only other significant variable in predicting RHC or referral for the PH cases.

To further understand how patients with PH are worked up and diagnosed, we looked at the specific test ordering. Overall, performing the necessary diagnostic work-up required for each case (eg, 2D echo, HRCT, ventilation/perfusion scan, or BNP test) varied widely (range, 0%–75%) and was generally poor (21.9%±14.1% correct). Overall, the most frequently ordered work-up was a 2D echo, which although necessary in every case, was not ordered in 41.1% of the PH cases. Among the 3 case types, the variation was

Table 2. Scores by Domains of Care and Case Type

	All cases, %		Idiopathic, %		CTEPH, %		PH-left heart disease/ PH-lung disease, %	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
History	65.4	15.5	61.4	14.8	68.2	13.2	68.2	14.3
Physical	66.0	21.4	66.6	21.0	66.1	21.9	65.9	21.4
Work-up	21.9	14.1	26.2	15.0	20.4	13.5	19.4	12.9
Diagnosis	46.1	36.3	54.4	38.6	39.0	34.9	45.8	33.4
Treatment	11.5	14.1	12.6	15.3	11.0	12.6	11.0	14.2
Overall CPV score	43.2	11.5	46.1	11.7	41.0	10.9	43.1	10.6
Needed work-up								
BNP	30.2	…	33.5	…	31.9	…	26.0	…
ABG	10.2	…	13.8	…	3.4	…	9.6	…
2D echo	64.3	…	72.5	…	59.6	…	60.7	…
High-resolution chest CT	36.1	…	50.0	…	26.4	…	30.1	…
Ventilation/perfusion scan	16.1	…	15.1	…	24.5	…	8.6	…
DLCO	13.5	…	17.0	…	11.3	…	11.9	…
6-min walk test	10.2	…	12.4	…	8.9	…	9.1	…
Suspect correct primary diagnosis	53.3	…	62.4	…	47.4	…	51.1	…
Postdiagnostic decisions								
Right heart catheterization	34.2	…	42.0	…	39.0	…	22.3	…
Referral to expert center for PH	12.2	…	23.9	…	10.7	…	2.9	…
Referral to pulmonary rehab	2.3	…	4.4	…	0.6	…	…	…
Order oxygen therapy	5.3	…	5.4	…	0.6	…	16.9	…

2D indicates 2-dimensional; ABG, arterial blood gas; BNP, B-type natriuretic peptide; CPV, Clinical Performance and Value; CT, computed tomography; CTEPH, chronic thromboembolic pulmonary hypertension; DLCO, diffusing capacity of the lungs for carbon monoxide; and PH, pulmonary hypertension.

notable, too. Echocardiography was not ordered 27.5% of the time in the IPAH cases, 40.4% in the CTEPH cases, 46.1% in the PH-LHD/CHF cases, and 62.2% of the time in the PH-lung disease case.

In other necessary work-up tests to make a presumptive diagnosis, physician performance was lower. BNP testing was not ordered on average more than two-thirds of the time (69.5%) regardless of the case type (66.5% for IPAH, 68.1% for CTEPH, and 74.0% for PH-LHD/CHF or PH-lung disease; P=0.199). HRCT provides detailed information on lung parenchyma, interstitial, and vascular abnormalities (eg, reticular or nodular opacities, hyperinflation, venous congestion, obstructing masses, lymphadenopathy) that may distinguish group 1 IPAH from the other PH groups. Physicians, overall, did not order HRCT 63.6% of the time (necessary in 8 of the 9 cases; not needed in 1 case where the diagnosis was chronic liver disease), ranging from 50.0% in the IPAH cases to 69.9% in the PH-LHD/CHF or PH-lung disease cases and 73.6% in the CTEPH cases (P<0.001). Alarmingly, ventilation/perfusion scans were not ordered 83.7% of the time (necessary in 7 of the 9 cases but not needed in either the chronic liver disease case or in the COPD with emphysema case). The 3 CTEPH cases had the highest order rate, but even here the ventilation/perfusion scan was missed 75.5% of the time versus 84.9% of the time for IPAH cases and 91.4% for PH-LHD/CHF or PH-lung disease cases (P<0.001 between case types).

Accuracy of Follow-Up Care

The follow-up care domain score measured whether physicians ordered the RHC or a necessary referral to a PH center plus necessary pharmacological/nonpharmacological interventions and was both highly variable and very low (11.5%±14.1%). There was no significant difference (P=0.420) across all 3 case types (Table 2). The definitive actions of physicians for patients with suspected PH is to order RHC or, for physicians who do not do RHC, to refer to a PH center. For the patients with PH requiring either RHC or referral, study participants ordered the procedure or made the referral 41.1% of the time (69.8% of these ordered RHC, 15.6% referred to a PH expert, and 14.5% did both),

with significant differences by case type (55.8% for IPAH, 44.0% for CTEPH, 12.3% for PH-LHD/CHF, and 32.4% for PH-lung disease; *P*<0.001). There was no difference by specialty (overall, 42.6% for pulmonologists versus 39.3% for cardiologists; *P*=0.486). Oddly, physicians ordered RHC or referral to an expert PH center at a higher rate in cases where PH was not the primary diagnosis compared with when it was (50.8% versus 41.1%; *P*=0.048).

Other items necessary for the treatment of PH were surprisingly low. For example, the rate of referral for pulmonary rehabilitation, which was needed in the 4 cases where the diagnosis was either IPAH or CTEPH, was only 2.4%. Similarly, the rate of providing oxygen therapy, which was required in the 2 cases for CTEPH, was only 5.6%.

Correlation Analyses

We looked at whether ordering a 2D echocardiogram for each of the different case types was associated with a greater likelihood of making the correct presumptive diagnosis of PH or doing an RHC or making the referral (Table 3). In the PH cases (ie, IPAH, CTEPH, LHD, and interstitial lung disease), we found those who ordered an echocardiogram were significantly more likely to make the correct primary PH diagnosis compared with those who did not (61.9% versus 30.7%; *P*<0.001). This difference was significant for all causes (*P*<0.05) except in the PH-lung disease case (46.4% versus 28.3%; *P*=0.112).

In addition to being helpful for diagnosing PH, ordering an echocardiogram also predicted whether an RHC or a referral to an expert PH center was done (52.1% for those who ordered an echocardiogram versus 25.1% for those who did not; *P*<0.001).

Table 3. 2-Dimensional Echocardiogram Use and Correct Presumptive Diagnosis Correlations, Where Necessary

	Correct presumptive diagnosis		*P* value
	No	Yes	
Ordered echo			
No	62.5	37.5	<0.001
Yes	37.3	62.7	
	RHC or referral to PH center		***P* value**
	No	**Yes**	
Ordered echo			
No	74.9	25.1	<0.001
Yes	47.9	52.1	
Correct presumptive diagnosis			
No	84.2	15.8	<0.001
Yes	32.7	67.3	

PH indicates pulmonary hypertension; and RHC, right heart catheterization.

Interestingly, in the non-PH cases, an echocardiogram was not indicative of better diagnostic accuracy (64.0% versus 60.4%; *P*=0.638) nor was it predictive of incorrectly ordering RHC (52.6% versus 38.9%; *P*=0.279). In addition, among those physicians who both ordered an echocardiogram and made the correct diagnosis of PH, a significant portion of physicians still failed to order RHC or signify referring the patient to an expert center for PH for each case. These values ranged from 20% in 1 IPAH case to 46% in the lung disease case.

Those who ordered a ventilation/perfusion scan for the IPAH and CTEPH cases were also significantly more likely to make the correct preliminary diagnosis and to order RHC or refer to an expert PH center. In the IPAH cases, those who ordered a ventilation/perfusion scan performed significantly better at correctly suspecting PH (81.5% versus 51.4%; *P*=0.005) and ordering RHC or referring to an expert PH center (77.8% versus 50.5%; *P*=0.010). Similarly, in the CTEPH cases, those who ordered a ventilation/perfusion scan were significantly more likely to suspect PH (87.2% versus 49.2%; *P*<0.001) and order RHC or refer to an expert PH center (68.2% versus 35.8%; *P*<0.001). By comparison, in the non-PH cases, ordering a ventilation/perfusion scan was not predictive of better diagnosis (60.0% versus 63.4%; *P*=0.764) or RHC/referral rates (64.3% versus 49.2%; *P*=0.284).

Finally, those who ordered an HRCT scan when necessary were also more likely to correctly suspect PH (60.4% versus 43.2%; *P*=0.001), although this significance varied by case type (IPAH, 62.5% versus 52.7% [*P*=0.246]; CTEPH, 71.4% versus 53.9% [*P*=0.047]; PH-LHD/lung disease, 46.5% versus 22.9% [*P*=0.005]). Physicians who ordered an HRCT scan were also more likely to correctly order RHC or refer to an expert PH center (51.0% versus 35.9%; *P*=0.002). However, when we looked at this by cause, it was only in the CTEPH cases when ordering an HRCT proved significant (59.5% versus 38.5%; *P*=0.018).

DISCUSSION

PH, although uncommon, is an important, progressive, and potentially treatable disease (eg, IPAH- and CTEPH-specific therapy), and misdiagnosis or late diagnosis can have dire consequences. Our current understanding of how patients with PH are evaluated is done retrospectively rather than dynamically as they go through the work-up and evaluation stages. We wanted to understand how these patients were evaluated and why diagnosis is often delayed or missed. In this study, we used standardized online simulated patients to identify and assess these gaps in clinical care.

We conducted a prospective cross-sectional study involving 219 physician specialists composed of

cardiologists and pulmonologists. A wide variation in care was found, with quality-of-care scores as measured for the CPVs ranging from 18% to 74%, regardless of case type. Overall, the quality of care was poor, most notably in the work-up, diagnosis, and follow-up care domains. More important, there was a poor preliminary diagnostic accuracy for PH, where both cardiologists and pulmonologists are challenged when either making a presumptive diagnosis of possible PH or ruling it out. All patients in this study presented with symptoms consistent with PH, and as such, PH should have been considered. However, whether PH was even considered was basically a coin flip. In cases where PH was present, the preliminary primary diagnosis of PH was only 49.1%. This parallels other real-world results that showed patients only received a correct definitive diagnosis of PH only 47.1% of the time.[18] For non-PH cases in our study, PH was incorrectly diagnosed 53.7% of the time. Interesting, among all of the study patients who presented with chronic dyspnea, physicians were significantly better at making the non-PH primary diagnoses compared with making a PH-related diagnosis (63.1% versus 49.1%; P=0.001). This suggests to us that physicians have a low clinical suspicion for PH.

These data suggest a couple of reasons why specialists may not be considering PH. Tests were not ordered when they would have been helpful. When a 2D echocardiogram or a ventilation/perfusion scan was ordered, this significantly increased the likelihood that physicians in this study looked for PH. Although echocardiography was needed for every case and was the most frequently ordered work-up, a significant fraction of physicians (41.1%) did not order an echocardiogram in the PH cases. Even more notable was that ventilation/perfusion scans, which were necessary in every case to rule out CTEPH, were not ordered 83.7% of the time. This observation provides another valuable insight for what it says about not ordering these tests: when physicians fail to order an echocardiogram or a ventilation/perfusion scan when it is needed, they are half as likely to consider PH as the diagnosis.

Ordering an RHC or referring to a PH expert is the definitive follow-up diagnostic approach for any patient suspected with PH. In this study, for the patients who required either RHC or referral, participating physicians only ordered the procedure or made the referral 41.1% of the time. In the non-PH cases, curiously, making the correct presumptive non-PH diagnosis, we did not see a decrease in orders for RHC or referral to PH expert (51.3% versus 50%; P=0.884). This further suggests that the work-up and recognition of PH is a challenge regardless of the underlying disease.

Ordering the following tests improved the chances of making a PH diagnosis: 2D echocardiogram (ordered in 60% of cases), ventilation/perfusion scan (ordered 16% of the time), and HRCT (ordered in 35% of cases). All increased the probability by 101%, 100%, and 39.7%, respectively. The low order rates seen here are broadly similar to those found in the PAH-QuERI (Pulmonary Arterial Hypertension–Quality Enhancement Research Initiative) study.[19] Ordering these tests meant that the physicians were 4.3 times more likely to do an RHC or refer to a PH expert. Alarmingly, however, among physicians who ordered an echocardiogram and made the preliminary diagnosis of PH correctly, 30% still did not do an RHC or make the needed referral to a PH expert, suggesting that some specialists are not clear on how to make the definitive diagnosis of PH.

Pulmonologists compared with cardiologists scored modestly higher in overall quality of care (+4.7% in multivariate regression modeling; P<0.001). Although some of this was driven by better PH diagnosis (+13.0%; P=0.007), most of the improvement came from a more thorough history and physical examination.

Early diagnosis of PH means more timely administration of evidence-based treatment choices, such as endothelin receptor antagonists, phosphodiesterase type 5 inhibitors, and prostacyclin pathway agents for PAH, and better patient outcomes.[20] The QR-BADGE study strongly suggests that physician specialists evaluating patients with unexplained or chronic dyspnea need to increase their clinical suspicion for PH. Ideally this would be done with a diagnostic tool that tests for PH regardless of the cause.

There are several limitations to this study. Although the clinical scenarios we used for the cases consisted of a single patient encounter, in the real-world scenario, it is possible that multiple return visits would have led to making the presumptive diagnosis of PH. That being said, this only confirms that diagnostic delay is a significant problem. Another limitation is that we did not control for the ability of the echocardiographer to recognize PH in this study. Instead, when a 2D echocardiogram was ordered, we assumed that cardiologists would identify possible PH 100% of the time, something that does not happen. Another limitation is that the pool of CPV cases used in this study did not include the subforms of PAH and group 5 PH, which are those patients with PH with unclear or multifactorial mechanisms (eg, from systemic or hematologic disorders) and represent a more heterogenous set with likely even more practice variation.[21] We did not measure several of the external factors, such as the health system, a systems-based approach, and collaborations. In addition, the familiarity of the individual participants to PH, which may influence their clinical approach to the simulated patients, was not measured in this study and was left to future research. Finally, we note that the participants encountered PH at a frequency of 2 of every 3 simulated patient cases that they cared for, which is markedly higher than the real-world incidence of PH.

Although there is general agreement that the early diagnosis of PH leads to better outcomes, the magnitude of its effect on the prognosis for the different groups of PH varies and is influenced by specific PH therapies (eg, group 4 has significantly better long-term survival than groups 1 and 2, whereas group 3 has the worst outcome).[1,22,23] Future studies are needed to determine if it is possible to close the presumptive and definitive diagnostic gaps we found in this prospective practice evaluation of patients with PH.

CONCLUSIONS

Using standardized online simulated patients, a wide range of variability in the clinical assessment—specifically in the preliminary evaluation and plan for definitive diagnosis of patients with PH—was found among physicians caring for patients with nonspecific symptoms of chronic dyspnea. This study shows that the diagnosis of PH is often delayed or missed, primarily because of a low suspicion of PH and underuse of key diagnostic tests and, when PH is considered, failing to do a definitive RHC—all indicating an opportunity to improve the quality of care of patients with PH.

ARTICLE INFORMATION

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Affiliations

QURE Healthcare, San Francisco, CA (E.d.B., D.P., I.C., J.W.P.); Norton Healthcare, Louisville, KY (J.W.M.); UC Health, Cincinnati, OH (J.M.E.); Janssen-Cilag GmbH, Neuss, Germany (J.L.); (J.W.P.) and University of California, Los Angeles, CA (J.W.P.).

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Supplemental Material

Table S1
Figure S1

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SUPPLEMENTAL MATERIAL

Table S1. Summary of pulmonary hypertension cases developed for patient case simulations for the QR-BADGE study.

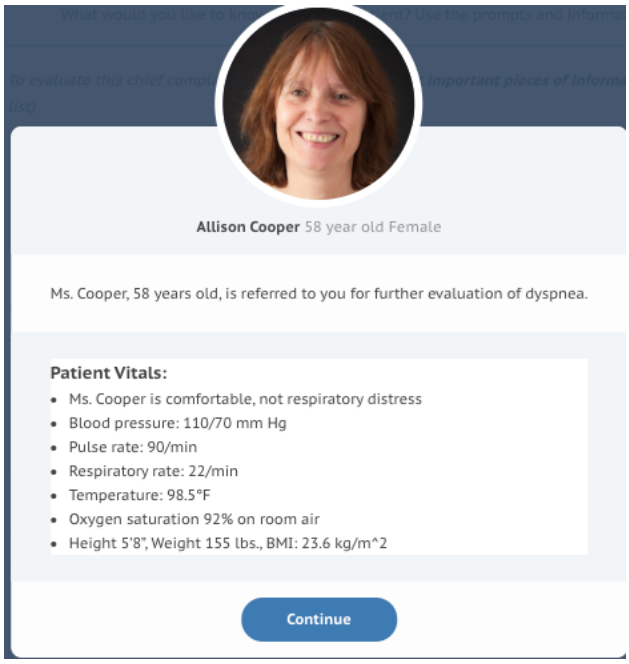
Case types	Case variants		
	Case variant A	**Case variant B**	**Case variant C**
Case type 1 *Pulmonary arterial hypertension (PAH) Group 1*	**Case description:** PAH WHO functional class II in a 52-year-old man with progressive dyspnea unresponsive to bronchodilators ***Diagnosis:*** *PAH probably idiopathic* ***Expected management:*** *confirm with RHC or referral to PH expert, ERA*	**Case description:** Disproportionate dyspnea in a 38-year-old obese woman with bronchial asthma despite therapy (PAH WHO functional class III) **Diagnosis:** PAH probably idiopathic **Expected management:** confirm with RHC or referral to PH expert, **E**RA + PDE5 inhibitor	**Case description:** Unexplained dyspnea in a 63-year-old woman with limited cutaneous scleroderma/CREST syndrome **Diagnosis:** Interstitial lung disease from scleroderma **Expected management:** Mycophenolate mofetil OR referral for possible pulmonary biopsy
Case type 2 *Chronic thromboembolic pulmonary hypertension (CTEPH) (Group 4)*	**Case description:** Exertional dyspnea in a 58-year-old woman with history of acute pulmonary embolism during tamoxifen treatment **Diagnosis:** CTEPH **Expected management:** confirm with RHC OR referral to PH expert, anticoagulation, oxygen therapy	**Case description:** A 49-year-old man with anginal chest pain but normal CAD testing **Diagnosis:** CTEPH **Expected management:** confirm with RHC OR referral to PH expert, anticoagulation, oxygen therapy, pulmonary rehab	**Case description:** Fatigue and edema in a 56-year-old man with chronic liver disease from chronic hepatitis C virus (HCV) infection **Diagnosis:** Budd-Chiari syndrome from HCV-related chronic liver disease **Expected management:** Treatment of HCV/CLD; referral to gastroenterologist, possible liver biopsy
Case type 3 *Pulmonary hypertension (PH) with no PH-specific therapy (Groups 2,3)*	**Case description:** Progressive dyspnea and easy fatigability in a 60-year-old woman with hypertension, HFpEF, CAD, and COPD **Diagnosis:** PH Group 3 **Expected management:** confirm with RHC OR referral to PH expert, aggressive COPD treatment	**Case description:** Chronic severe dyspnea in a 64-year-old man with with long-standing HFpEF and hypertension **Diagnosis:** PH Group 2 **Expected management:** confirm with RHC OR referral to PH expert, maximize guideline-directed medical treatment, oxygen therapy	**Case description:** Persistent dyspnea and elevated pulmonary artery pressure in a 55-year-old man despite maximal therapy for COPD **Diagnosis:** Severe COPD with upper lobe emphysema **Expected management:** Aggressive COPD management, including possible lung volume reduction surgery

Abbreviations:

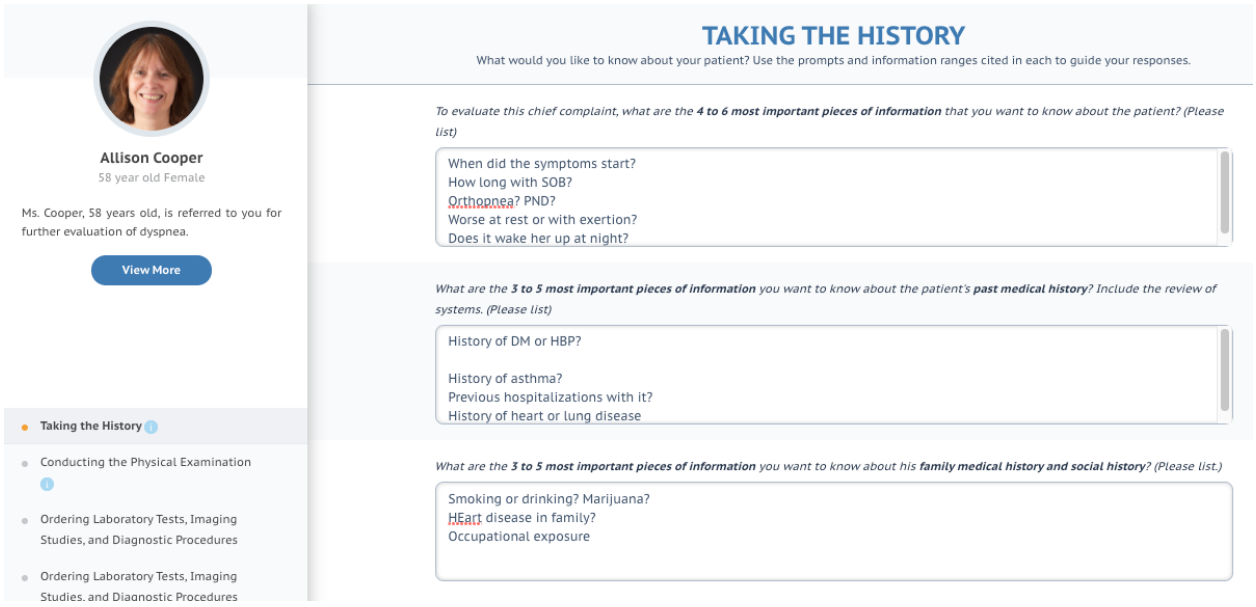
COPD – chronic obstructive pulmonary disease; CREST – calcinosis, Raynaud's phenomenon, esophageal dysfunction, sclerodactyly, telangiectasia; ERA – endothelin receptor antagonist; HFpEF – heart failure with preserved ejection fraction; PAH – pulmonary arterial hypertension; PDE5 – phosphodiesterase-5; PH – pulmonary hypertension, RHC – right heart catheterization, WHO – World Health Organization

Figure S1. Sample CPV Vignette Walkthrough.

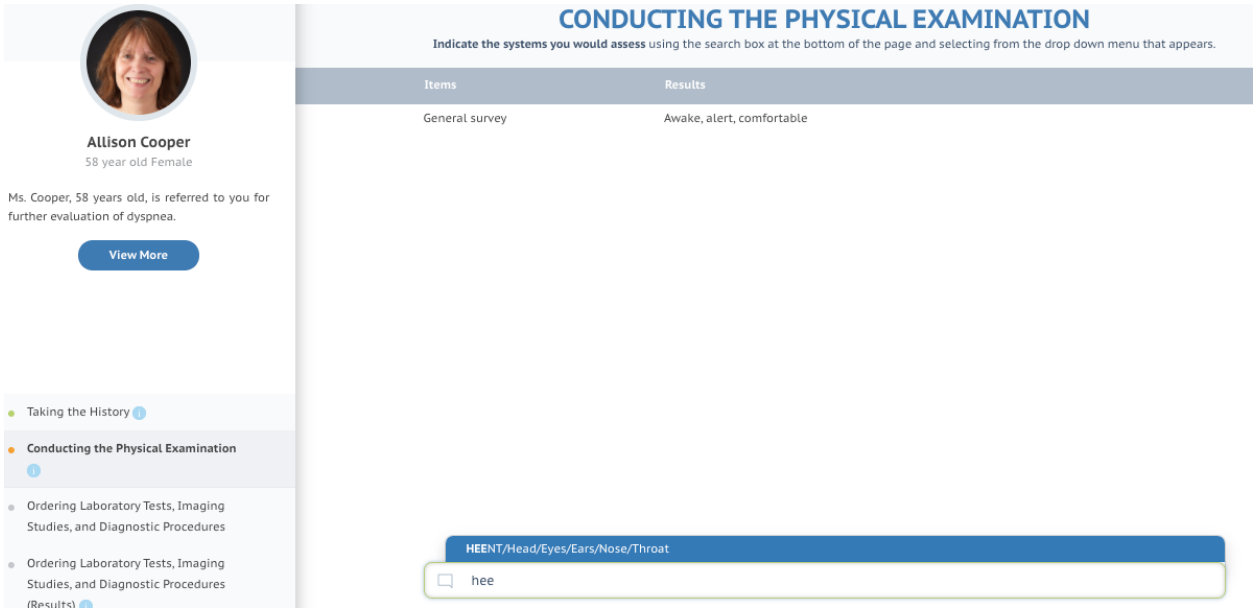
At the beginning of each case, physicians are introduced to their patient, including age, sex, vitals, and current complaint:



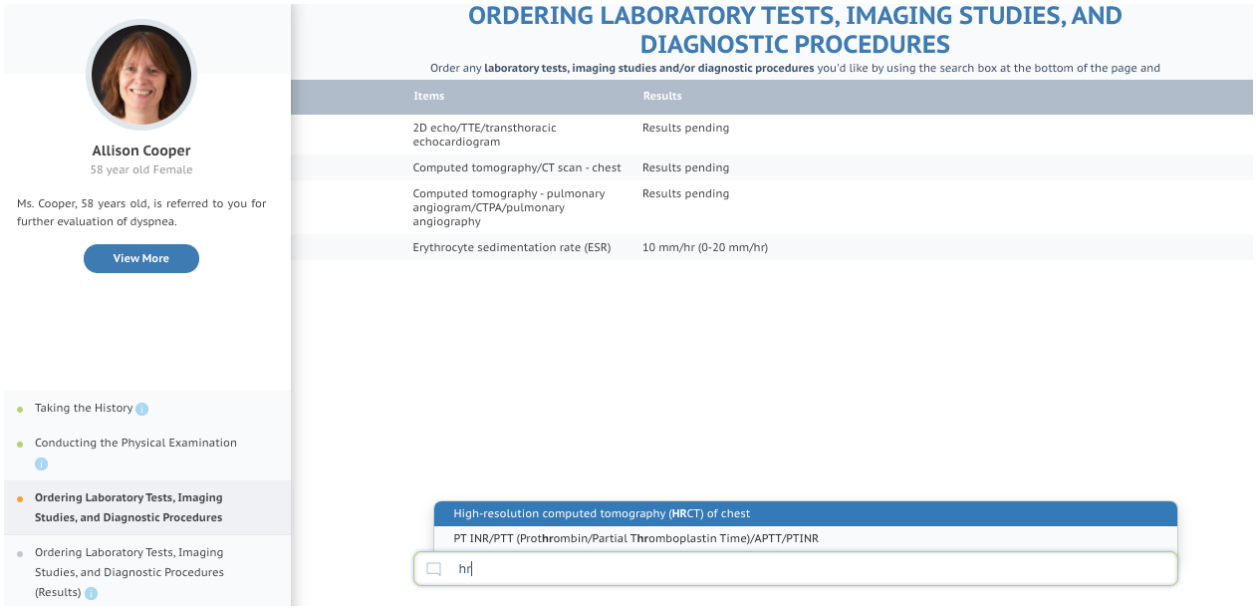
Once the clinical encounter is initiated, the physician is asked to care for their online simulated patient as they would any other patient in their clinic. This begins with taking a history, where they are allowed to enter open-ended questions about the patient's history:



After soliciting a history and receiving the results of those questions, the physician is then asked to perform a physical exam. Here, we use a typeahead to limit the number of available options, and results are returned instantaneously:



Once the physician has completed their physical, they can then order diagnostic workup to aid in their diagnosis:



Here, the doctor ordered a 2D echocardiogram (among others). Having done so, they would then receive results on what they ordered:

The Echo Lab

Transthoracic 2-Dimensional Echocardiogram and Doppler Report

Patient Name: Allison Cooper Age: 58 years Sex: F Race: Caucasian
BP: 110/70 mm Hg Heart rate: 90 bpm Height: 170 cm Weight: 70 kg Body surface area: 1.82 m^2
Indication: evaluation of unexplained dyspnea

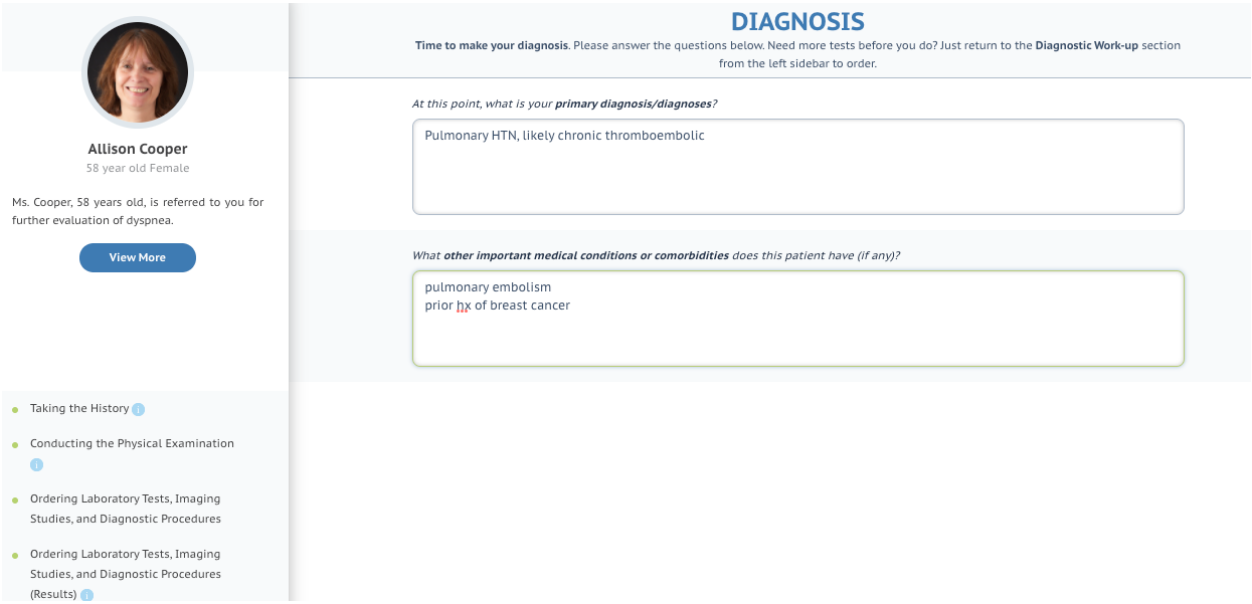
M-MODE AND 2D MEASUREMENTS			DOPPLER STUDIES		
Left Ventricle	Patient	**Normal**	**Mitral Valve**	Patient	Normal
LV end-diastolic dimension (cm)	**4.8**	< 55 (M) < 50 (F)	Peak velocity (m/sec)	**1.0**	
LV end-systolic dimension (cm)	**3.4**		Peak gradient (mm Hg)	**4.0**	-
IV septal wall thickness, D (cm)	**0.8**	< 1.3	Pressure half-time (msec)	**44**	< 70
IV septal wall thickness, S (cm)	**1.2**		Valve area (cm^2)	**5**	> 4
Posterior wall thickness, D (cm)	**0.8**	< 1.3	E/A ratio	**1.1**	
Posterior wall thickness, S (cm)	**1.2**		E/e'	**6**	< 8
LV mass index (g/m^2)	**70**	< 115 (M) < 95 (F)	**Aortic Valve**		
Ejection fraction, Simpson's (%)	**55**	> 52 (M) > 52 (F)	Peak velocity (m/sec)	**1.0**	< 1.7
Right Ventricle			Peak gradient (mm Hg)	**4**	< 12
RV mid diameter, D (cm)	**3.3**	< 3.5	Mean gradient (mm Hg)		-
Wall thickness (cm)	**0.4**	< 0.5	Valve area (cm^2)	**3**	> 2
Tricuspid annular plane systolic excursion (cm)	**1.8**	> 1.7	**Pulmonic Valve**		
RV fractional area change (%)	**36**	> 35	Peak velocity (m/sec)	**0,6**	
Left atrium			Peak gradient (mm Hg)	**1.4**	-
Volume index (mL/m^2)	**30**	< 34	Acceleration time (msec)	**97**	
Right atrium					
RA minor axis, BSA_i (cm/m^2)	**2.2**	< 2.2	**Tricuspid Valve**		
RA volume, BSA_i (mL/m^2)	**2.7**	< 3.2 (M) < 2.7 (F)	Pressure half-time (msec)	**28**	
Pulmonary artery diameter (cm)	**2.5**	< 2.9	Valve area (cm^2)	**8**	> 7
LV outflow tract diameter (cm)	**1.8**		Peak TR velocity (m/sec)	**3.1**	
Proximal ascending aorta (cm)	**2.5**	< 3.4 (M) < 3.1 (F)	RA pressure, estimated (mm Hg)	**8**	< 3
Inferior vena cava (cm)	**2.0**	< 2.5	Systolic PA pressure (mm Hg)	**46**	< 30

D – diastole, S – systole, M – male, F – female, BSA_i – indexed to body surface area

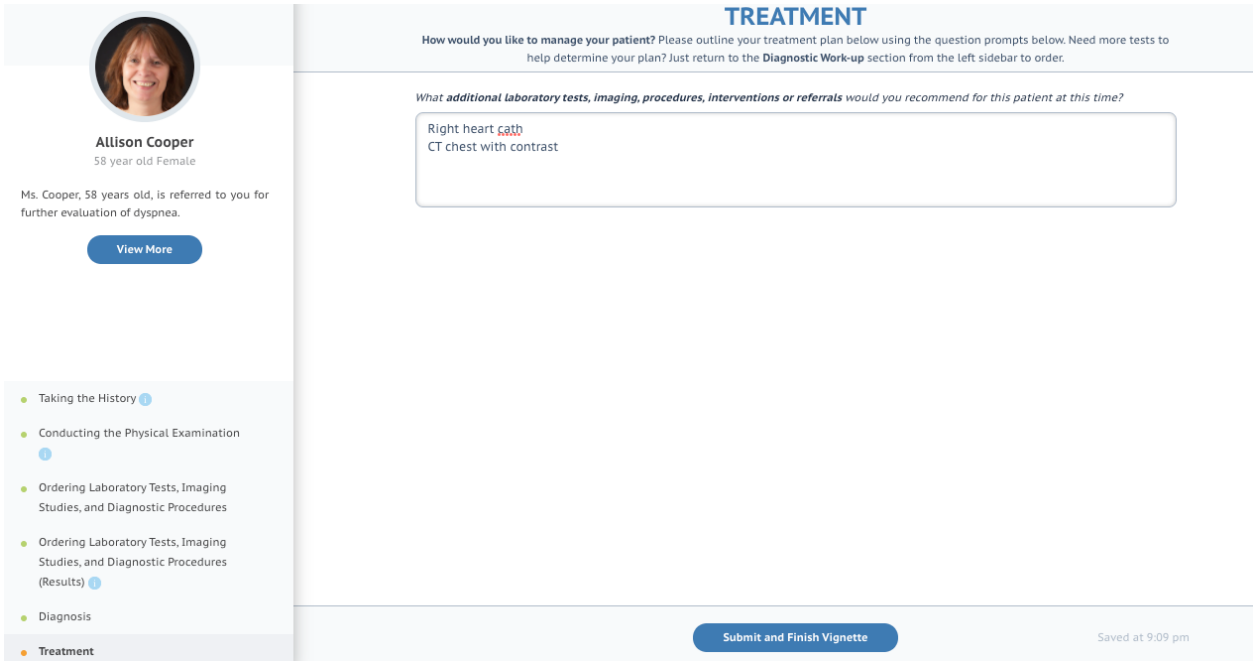
Description:

- Normal left ventricular mass index and relative wall index; normal contractility and global systolic function; with no obvious evidence of diastolic dysfunction
- Normal right ventricular cavity size with borderline wall thickness and normal systolic function
- Normal left atrial, main pulmonary artery and aortic root dimensions
- Top-normal right atrial dimensions
- Normal mitral inflow E/A velocity ration
- Structurally normal tricuspid valve with mild regurgitation
- Normal inferior vena cava caliber with <50% inspiratory collapse
- Estimated systolic pulmonary artery pressure of 46 mm Hg by peak TR gradient; with pulmonic regurgitation
- No obvious shunt anomaly demonstrated

After the doctor has made sure they have elicited all the information they need in the history, physical exam, and diagnostic workup, they then make a preliminary diagnosis:



Finally, after their preliminary diagnosis, they are asked to outline a detailed treatment plan in free text:



After submitting their treatment plan, the clinical encounter (and vignette) ends.