Original Article

Comparison between Emergency Severity Index plus peak flow meter and Emergency Severity Index in the dyspneic patients with chronic obstructive pulmonary disease: A randomized clinical trial

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ABSTRACT

Introduction: It is unclear whether the Emergency Severity Index (ESI) can identify high-risk patients with Chronic Obstructive Pulmonary Disease (COPD). This study aims to compare the mistriage rates of the ESI plus the Peak Expiratory Flowmeter (PEF) approach and ESI approach among dyspneic patients with COPD.
Methods: This study was a randomized clinical trial conducted between July and October 2018. We randomly assigned COPD patients with dyspnea to the ESI + PEF or ESI groups. Triage levels, disposition rates, number of resources used, and time to first physician contact were compared in patients admitted to the Intensive Care Unit (ICU), the Pulmonary Care Unit (PU), or discharged from the ED. Reliability of the ESI was evaluated by using the interobserver agreement (Kappa).
Results: Seventy COPD patients were equally assigned to the ESI + PEF and ESI groups. The under-triage rates were 11.42% and 0%, the over-triage rates were 31.42% and 2.85% in the ESI and ESI + PEF groups, respectively. The triage levels of the patients admitted to the ICU (2 vs. 3), the PU (2 vs. 4), or discharged from the ED (3 vs. 2) were significantly different between the ESI + PEF and ESI groups.
Conclusions: Addition of PEF to the ESI provides a more accurate method for triaging COPD patients compared to ESI alone. We recommend using PEF for the triage of COPD patients in the ED.

1. Introduction

Dyspnea is a major symptom of Chronic Obstructive Pulmonary Disease (COPD).[1] The most common factors used to assess the respiratory function of these patients in triage are currently the Respiratory Rate (RR) and Blood Oxygen Saturation (SpO_2) level measured by a pulse oximeter. Although RR is a highly sensitive attribute of the patient's condition and a primary indication of illness severity, measurement of the RR is neglected since it is time-consuming and difficult to measure; thus, it is rarely monitored and recorded in the ED.[2] An audit performed by Parker showed that RR was monitored only in relation to the patient's chief complaints, recorded in less than one-third of patients and less than half of those had the complaint of dyspnea.[3] At present, no measurement device similar to what is available

for temperature, heart rate, and blood pressure is readily available for the measurement of RR in the triage area, which may be the primary factor of neglecting RR measurement. The RR measurement provides information that SpO_2 cannot.[4] COPD patients may have normal SpO_2 values, while RR is high and abnormal.[3] In this regard, O_2 measurements by pulse oximetry in COPD patients are estimated higher than those found in the blood, which is the most common in patients with chronic bronchitis.[5] The use of a pulse oximeter to determine SpO_2 in these patients can only be trusted in cases where the SpO_2 is normal and it is not reliable in case of hypoxia. The importance of the precise measurement of the O_2 saturation is further increased when it was shown that in these patients an O_2 saturation of 92% and more with an invasive oxygen therapy is associated with an increase in the mortality.[5] However, the pulse oximeter is not a precise instrument for the

monitorization of ventilation in COPD patients and does not indicate the severity of the illness.[4] Moreover, hypothermia and hypotension further limit the use pulse oximeter in the triage area. Given the great importance of monitoring respiratory function in these patients and a significant failure in conventional measurement methods, the use of complementary approaches is essential.

The Peak Expiratory Flowmeter (PEF) comprises a suitable strategy to detect patients who have a disease exacerbation and monitor the symptoms of the disease. It is also an appropriate method for screening patients who have suffered from airway duct stenosis but have not yet been diagnosed with COPD. The PEF can provide a reliable estimate of the respiratory state of these patients. Although this method has low accuracy for estimating the Forced Expiratory Volume in the 1st second (FEV1) in cases of mild airway stenosis, it has a significant clinical acceptance because of its inclusiveness, availability, affordability, and acceptable accuracy, as well as its good performance in patients with moderate to severe airway stenosis.[6,7] The PEF has shown highly satisfactory results in monitoring disease progression and response to treatment and determining the level and severity of illness in asthma patients.[8] Another important advantage of this technique is that it can alert the physician for the worsening of asthma even before a person feels symptoms of asthma exacerbation.[9,10]

The ESI is a five-level emergency department triage algorithm, initially developed in 1999. It provides clinically relevant stratification of patients into five groups from 1 (most urgent) to 5 (least urgent) on the basis of acuity and resource needs. ESI triage is the preferred method for prioritizing patients with COPD in the triage area, and the decision-making is initially based on a RR > 20/min and a SpO2 < 92%.[11]

Due to the abovementioned severe limitations in measuring RR and SpO_2 and the specific benefits of the PEF, we hypothesized that the use of PEF measurement with the ESI triage may be useful in prioritizing and better diagnosing patients with COPD. Patients with the complaint of dyspnea who are referred to the ED are monitored at the triage to identify critically illness. The under-triage rate in the ED for COPD was reported as 8.57% which is significant; hence, measures to reduce this kind of triage error is necessary.[12] Using the PEF is convenient, inexpensive, and requires less skill and time to screen airway obstruction in areas where spirometry is unavailable.[13,14]

Therefore, it this study, we aimed to evaluate the effect of adding PEF to the ESI triage scale on mistriage rates, and time indices in COPD patients referred to the ED with the complaint of dyspnea.

2. Methods

2.1. Setting and design

The randomized clinical trial with a 6-h follow-up to obtain short-term outcomes was conducted between July to October 2018 in the Imam Reza Hospital, Mashhad, Razavi Khorasan, Iran. The effect of the use of ESI + PEF or ESI on the mistriage rates of COPD patients in the ED was compared. The intervention group was composed of patients on whom the ESI + PEF was conducted. The control group was comprised of patients on whom the ESI (ver. 4) was performed.

2.2. Participants, randomization and sampling

Patients with a chief complaint of dyspnea who presented to the ED were included if they had either a history of COPD or a hospitalization due to respiratory problems. Sampling was conducted over weekdays except for the night shift. Eight registered nurses are allocated to the triage room on weekdays and those nurses were unaware of one another's decisions in both groups. Included patients were randomly assigned to the intervention (ESI + PEF) and control (ESI) groups in 1:1 allocation ratio.

2.3. Outcomes

The age, gender, vital signs [RR, SpO_2, blood pressure (BP), pulse rate (PR)], triage level, and clinical outcomes (number of used resources, ED admission, Pulmonary unit (PU) admission, Intensive Care Unit (ICU) admission, and ED discharge) were recorded during the first 6 h of hospitalization in the ED. The time to oxygen therapy and physician visit were recorded. The patients were excluded if, 1) unable to speak due to dyspnea, 2) they were not diagnosed with COPD by the pulmonologist, 3) they were transferred to the other hospital, and 4) their documents were incomplete.

2.4. Interventions

ESI + PEF (intervention group): Patients were assigned to ESI triage level 2 if their $SaO_2 < 92\%$, or their PEF reading was at the Red zone; assigned to triage level 3 if their SaO_2 was in the normal range and their PEF reading was at the Yellow zone; and assigned to level 4 or 5 based on the number of required resources if their SaO_2 was in the normal range and their PEF reading was at the Green zone. Level 4 was defined as patients who need one resource, and level 5 was defined as patients who do not need any resource in the ED. We did not consider RR because it is not measured in routine clinical practice.

ESI (control group): Since the ESI is a valid triage scale already used in Iran, the ESI (ver.4) was used as a validated triage tool to assign triage levels.[15,16] The reliability between the two triage nurses was assessed using Kappa statistics based on 10 cases.

2.5. Measurement

Microlife PF 100® (Microlife AG Swiss Corporation, Switzerland) was used to measure the PEF in the triage room. It is a digital measuring device for measuring the PEF and FEV1 in one second in respiratory monitoring. The accuracy is (± 20 L/min) for the PEF and (± 0.1 L) for the FEV1. The test-retest reliability was assessed using Pearson's coefficient based on 10 cases.

2.6. Definitions

Mistriage was defined by an expert panel and consists of under- and over-triage. Under-triage rate was defined as the percentage of ICU patients who had received a triage level of 3–5 and PU patients who had received triage level 5. Over-triage rate was defined as the percentage of discharged patients who had received triage level 1 or 2 and PU patients who had received triage level 1 in the current study. Resources were defined by the Emergency Severity Index (ESI) Implementation Handbook (Ver. IV). The number of different types of resources, not individual tests (e.g., complete blood cell count (CBC) and electrolytes: one resource; CBC and chest x-ray: two resources) were counted.

2.7. Statistical analysis

The continuous variables were expressed with means, standard deviations (SDs), and 95% confidence intervals. Categorical variables were expressed with counts and percentages. Groups were compared using the independent samples *t*-test, Mann–Whitney *U* test, or Kruskal–Wallis statistics according to distribution patterns, and number of groups. The SPSS 16.0 statistical software package (SPSS Inc., Chicago, IL, USA) was used. A post hoc power analysis based on the proportions of mistriage showed that the power is higher than 0.80 in ICU, PU, and discharged patients. This study was conducted with the permission of the Ethics Committee of Mashhad University of Medical Sciences (IR.MUMS.REC.1397.083). Informed consent was also obtained from patients in the ED. The study was registered at the Iranian Registry of Clinical Trials (IRCT20180410039258N1).

Table 1

Comparison of baseline characteristics between ESI + PEF and ESI groups.

Characteristics	All patients (n = 70)	ESI + PEF group (n = 35)	ESI group (n = 35)	P value
Age, mean (SD)	69.70 (14.03)	69.11 (13.04)	70.28 (15.12)	0.730
Male gender, n (%)	41 (58.6)	21 (30.0)	20 (28.6)	0.500
Mode of arrival; walking, n (%)	33 (47.1)	22 (31.4)	11 (15.7)	0.008
Triage level, median (IQR)	2 (1)	2 (1)	3 (2)	0.070
Level II, n (%)	36 (51.4)	22 (61.1)	14 (38.9)	
Level III, n (%)	20 (28.6)	8 (66.7)	12 (33.3)	
Level IV, n (%)	14 (20.0)	5 (35.7)	9 (64.3)	
Number of Resources, median (IQR)	6 (2)	6 (2)	6 (2)	0.871
Level II, median (IQR)	6 (2)	6 (2)	6 (2.25)	0.160
Level III, median (IQR)	6 (2)	6 (0.75)	7 (2)	0.130
Level IV, median (IQR)	6 (3)	5 (6)	6 (2)	0.360
Outcome				
Discharge, n (%)	27 (38.6)	11 (15.7)	16 (22.9)	0.450
Pulmonary unit, n (%)	33 (47.1)	18 (25.7)	15 (21.4)	
ICU, n (%)	10 (14.3)	6 (8.6)	4 (5.7)	
Triage duration (min), mean (SD)	1.46 ± .44	1.65 ± .50	1.27 ± 0.28	0.001
Time to O_2 therapy (min), mean (SD)	13.29 ± 19.28	4.37 ± 5.52	21.45 ± 23.46	0.001
Time to Physician visit (min), mean (SD)	23.0 ± 24.61	13.97 ± 13.58	32.02 ± 29.62	0.002
Time to Pulmonogist visit (min), mean (SD)	128.49 ± 150.15	73.13 ± 63.14	182.06 ± 187.63	0.004
PEF (L/min), mean (SD)	–	104.14 (62.5)	–	–
Systolic BP (mmHg), mean (SD)	134.21 ± 19.53	136.02 ± 17.16	132.40 ± 21.75	0.441
Diastolic BP (mmHg), mean (SD)	83.14 ± 13.35	82.79 ± 10.37	83.48 ± 15.86	0.832
Heart rate (bpm), mean (SD)	107.48 ± 13.00	109.2 ± 13.32	105.77 ± 12.63	0.273
Respiratory rate (per min), mean (SD)	26.71 ± 9.96	28.57 ± 13.09	24.85 ± 4.75	0.120
O2 Saturation (%), mean (SD)	89.18 ± 5.49	88.42 ± 6.55	89.57 ± 4.07	0.246
Temperature (C), mean (SD)	37.1 ± 0.25	37.10 ± 0.19	37.11 ± 0.29	0.950

3. Results

Eight patients were excluded from the study (5 in ESI + PEF, 3 in ESI) because of a final diagnosis other than COPD. Therefore, the analysis was performed on 70 patients, 35 in ESI + PEF and 35 in the ESI group. The baseline characteristics of the study population and groups are shown in Table 1. The number, percentage and median triage levels of patients admitted to ICU, and PU, and patients discharged from the ED are also presented in Table 1. The rates of undertriage were 0.00% and 11.42%, and over-triage were 2.85% and 31.42% for the ESI + PEF and ESI groups, respectively. Correct triage rates were 97.15% in ESI + PEF and 57.14% in ESI groups. There is a significant difference between the mistriage (overtriage/undertriage) and correct triage rates between two groups (p = 0.001).

The triage level was compared between the ESI + PEF and ESI groups among ICU, PU, and patients discharged from the ED (Table 2). Triage level was significantly different between the ESI + PEF and ESI groups (p < 0.002) in regard to patients admitted to the ICU (p < 0.01), PU (p < 0.001), and patients discharged from the ED (p < 0.001) (Table 2).

In the ESI + PEF group, number of the resources used was not significantly different among triage levels (p = 0.068), and there was also no significant difference among triage levels in the ESI group (p = 0.422). In the ESI + PEF group, used resources was not significantly different among ICU patients, PU patients, and discharged

patients (p = 0.388), and there was also no significant difference among these patients in the ESI group (p = 0.124).

Dyspneic patients were triaged by four and one triage nurses for the ESI and ESI + PEF groups, respectively. The median ED experience of the nurses were five years for the ESI group and six years for the ESI + PEF group. The kappa coefficient of reliability between nurses was almost perfect in the ESI group (kappa 0.81, 95%CI: 0.63–1.00). The test-retest reliability was 0.99, which is assessed via a Pearson's coefficient to assess the PEF reliability.

4. Discussion

We found that mistriage rate was significantly lower in the ESI + PEF group compared to the ESI group. The median triage level of ICU patients was significantly different between the two groups (2 vs. 3). Also, 100% of the ICU patients were assigned to triage level 3 by the ESI scale. In contrast, no ICU patients were assigned to triage level 3 or higher by the ESI + PEF protocol. These findings indicated that undertriage is remarkable (11.42%) in the ESI group. This may be because we excluded patients with severely unstable vital signs, and so the ESI failed to recognize high-risk patients with stable vital signs ($SpO_2 > 92\%$). The privilege of ESI + PEF is associated with the ability of the PEF to reveal ventilation insufficiency despite a stable condition. High-risk criteria cited on ESI level 2 are dependent on nurses' knowledge of COPD, so this may become a source of discrepancy in

Table 2

Comparison of patients' characteristics between ESI + PEF and ESI groups regarding the status of admission.

Number of used resources (N in ESI + PEF group/N in ESI group)	All (n = 70)	ESI + PEF (n = 35)	ESI (n = 35)	P value
in discharged patients (7:15)	6 (2)	6 (2)	6 (2)	0.53
in PU patients (18:15)	6 (2)	6 (2)	6 (2)	0.76
in ICU patients (6:4)	8 (2)	8 (2)	8 (1.5)	0.91
Triage level	(n = 70)	(n = 35)	(n = 35)	
of discharged patients (11:16)	2 (1)	3 (1)	2 (1)	0.001
of PU patients (18:15)	2 (2)	2 (0)	4 (1)	0.001
of ICU patients (6:4)	2 (1)	2 (−)	3 (−)	0.001

triage decisions. In this regard, Bergs et al. showed that the majority of the mistriages that occurred on ESI level 2 were undertriage.[17] High-risk criteria in the ESI may be misinterpreted by triage nurses,[18] who differ in terms of work experience, knowledge, and skills. This difference can lead to an increased rate of undertriage in the ESI triage system. The undertriage rate is inconsistent among studies due to the substantial heterogeneity in the patient case mix and triage scales. Grossmann et al. reported an undertriage rate of 24.2%,[19] and Storm-Versloot et al. reported an undertriage rate of 14%.[20] Both studies used a general case mix of patients in the ESI triage system and calculated the undertriage rate based on an expert panel opinion. Therefore, it is expected that the undertriage rate will rise dramatically when an expert panel opinion is used because the interobserver heterogeneity between the expert panel and triage nurses may increase the undertriage rate. In the current study, the final disposition (ICU admission) was used to calculate the undertriage rate so that it may overestimate the undertriage rate among COPD patients.

The triage level of patients who were discharged from the ED (up to 6 h) was significantly different in the two groups (3 vs. 2). However, 9.1% of the discharged patients in the ESI + PEF group and 68.8% in the ESI group had received triage level 2. It can be said that the ESI does not help COPD patients in being assigned to triage level 4 or 5 even if they are not severely ill because the ESI relies on probable resource consumption. Oxygen therapy and an injection of hydrocortisone may prepare COPD patients for discharge. They may have discharged after a few treatments because changes in vital signs are not always critical.

As indicated earlier, the rate of over-triage in the ESI group is higher than that of the ESI + PEF (31.42% vs. 2.85%). It was expected that some of the discharged patients might be placed on triage level 4. It should also be noted that 68.8% of discharged patients in the ESI group had received triage level 2. This indicates that vital sign criteria in level 2 are too sensitive to triage COPD patients.

In this vein, the triage level of PU patients was significantly different between the two groups (2 vs. 4). Sixty percent of patients were assigned to level 4 in the ESI group, while no one in the ESI + PEF group received a level other than 4. Therefore, it can be said that PEF can help triage COPD patients more effectively.

The mean number of the resources used is expected to be associated with the triage level in the ED. A valid triage scale predicts a higher number of used resources for most severely ill patients.[21] However, the mean number of the resources used was not significantly different between groups. ICU patients used more resources than any other patients, and discharged patients used fewer than any other patients. Physicians tend to order a complete therapeutic protocol for most patients, so this may minimize the relation between the number of resources used and other outcomes in our ED.

Overall, the PEF reflects the pulmonary function and provides a direct parameter from the lungs. It is a useful device for prioritizing COPD patients since vital signs criteria are not conclusive. COPD is a chronic condition that tends to fluctuate repeatedly over time. It is possible that the PEF helps triage nurses recognize true exacerbation from false positives.

4.1. Limitations

There were several limitations to this study. Although the reliability of nurses' decision was almost perfect in both groups, triage nurses may be regarded as a part of the difference in the outcome. The triage nurses had more than five years of experience in the ED, and they were unaware of the nurses' decisions in the comparison group. A Chi-square analysis showed a significant difference between triage levels (2 ver. 3 and 4) and SpO_2 (>92% vs. <92%) in the ESI group, meaning that patients with SpO_2 >92% were regularly assigned to triage level 2 and vice versa (p < 0.005). This shows that the probability of bias in triage decisions is not significant because decisions were strictly based on vital signs in the ESI protocol. Patients who present to the ED with a chief

complaint of dyspnea were included if they had either a history of COPD or a hospitalization due to respiratory problems. History of COPD or hospitalization was based on the patients' statement. This may not be subject to bias because patients who were not diagnosed with COPD by the pulmonologist during their hospital stay were excluded.

5. Conclusion

The use of PEF along with the ESI scale may provide a more accurate method for COPD patients in triage since it helps clinicians to correctly identify high-risk patients with COPD. The ESI scale was associated with a remarkable mistriage rate in COPD patients with the complaint of dyspnea. In conclusion, we recommend the use of PEF to triage COPD patients in the ED.

Authorship

A.M. developed the concept of study; all authors contributed to the collection of the data, MT.SH. and A.M. performed data analysis and M.H. and A.M. wrote the draft, J.M. and M.E. critically reviewed manuscript, MT.SH. and M.E. provided administrative support. All authors approved the final manuscript.

Availability of data and materials

Data can be provided under permission of the Vice Chancellor of Research in Mashhad University of Medical Sciences.

Conflicts of interest

There is no conflict of interest.

Informed consent

All patients provided informed written consent as approved by the Vice Chancellor of Research in Mashhad University of Medical Sciences.

Ethical approval

The ethical approval of study was granted from the ethics committee of the Vice Chancellor of Research in Mashhad University of Medical Sciences.

Human rights

All subjects voluntarily participated in the study after informed consent was signed.

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